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Number	List of articles	Pages
1	Investigating the effect of Parasil herbal medicine on the growth performance and mortality rate of the broiler chickens	5-9
2	Investigating the effect of herbal medicine Timosil on antibody titer and strengthening the immune system of broiler chickens	10-14
3	Examining the effect of exosomes on fertility	15-21
4	Investigating the effect of vigor stimulator on the morphological properties and growth factors of tomato plants	22-30
5	The Effect of Drought Stress on the Performance of Wheat Grain Crops	31-36
6	The effect of drought stress on the physiological, phenological, and morphological traits affecting yield and seed oil percentage of sunflower(Helianthus) cultivars.	37-41
7	Effect of drought stress on phenological traits on rapeseed (Brassica napus L.) yield	42-45
8	Investigation of microwave pretreatment on the production of pre-gelatinized starch (review)	46-56
9	Identifying the impact of earthquakes on the city form and providing solutions based on the smart city to make decisions due to potential incidents (case example: Tehran)	57-64
10	Advances in Sustainable Architecture and Energy Efficiency	65-76
11	Seismic Risk Assessment of Urban Road Network	77-91
12	Investigating the Potential of Graphene Aerogels in Combating Marine Oil Pollution	92-102
13	Safflower, Moringa, and Salicornia Biodiesel: A Comparative Analysis of Sustainable Fuel Alternatives	103-109
14	Exploring the Potential of Biosorption By Algae: A Sustainable Solution for Water Treatment	110-115
15	Mercury Removal by Biochar and Activated Carbon: An Effective Approach for Environmental Remediation	116-121
16	Visualizing The Strategic Plan of an Organization to Monitor KPIs Using a Dashboard Development Approach. Case Study: Computer Science Faculty of Allameh Tabataba'i University	122-138
17	Analysis of bicycle traffic in the city and feasibility of bicycle routes in urban spaces (case example: Tehran)	139-148

Number	List of articles	Pages
18	Application of Municipal Sewage Sludge Ash for Waste-activated Sludge Thickening and Dewatering: a Comparative Study	149-160
19	Investigation of the Properties of Masonry Mortar Containing Recycled Aggregate and Zeolite with a Focus on Sustainable Development and Green Mortar	161-173
20	Overview of Corrosion of Implants with TiAl6V4 Titanium Alloys in a Body-Simulating Environment	174-181
21	A new fuzzy-interval regression method with one approach	182-196
22	Dual approach for minimizing quasiconvex functions over closed convex cones	197-214
23	Electrical and Optical Properties of CsPbI ₂ Br and its Variants: A Comparative Review	215-239
24	Antifungal effect of 4 plant species against aflatoxin production of <i>Aspergillus flavus</i>	240-242
25	Donkey's Milk; A Novel health-promoting Dairy: A Scoping Review	243-252
26	The use of digital technology as part of the consolidation of lexical memorization in languages: The Ankara University Private Foundation & Anatolian High School (ANKU) in Ankara	253-265
27	A Research on the Diversity of Poetic Vocabularies; Study of "Layla and Majnun" Narrative Poem in the Works of Nizami, Jami, and Amirkhosro Dehlavi Based on the Theory of Johnson	266-275
28	Contrastive Analysis of Surah Al-Fatiha and Its English Translations As a Semantic Corpus-Based- Case Study	276-281
29	The Other in Toni Morrison's A Mercy: A Zizekian Reading	282-289
30	Study of the relationship between critical self-criticism and social anxiety with fear of failure among girls (case study: students of the first middle years of the shahid Chozukulu high school in Pakdasht	290-297
31	Virtual power plant: A review on Components, Models, Types and Scheduling	298-310
32	Enhancing Operational Reliability and Efficiency in Architectural and Automotive Glass Production through Integration of Tempering-Furnace Power-Driving UPS with SCADA System	311-322
33	Trademarks: A Comparative Analysis of Unauthorized Use in Iran, South Korea, and China	323-332
34	Legal guarantees in construction and review of construction contracts and property rights in construction projects	333-345

Number	List of articles	Pages
35	A Comparative Study of the Social and Political Base of Groups and Parties in the Formation of the Constitutional Movement and the Islamic Revolution of Iran	346-361
36	Investigating and analyzing the performance of industrial automation and (PLC)	362-369
37	Application of PMSM with dq Reference Frame in Electric Vehicles	370-380
38	Copper nanoparticles and investigating the antimicrobial and anticancer effects of these particles (A review study)	381-392
39	Fabrication and Investigation the Structural and Morphological Properties of MoO ₃ /Ag/Cu/MoO ₃ Multilayer Nanostructures	393-396
40	Investigation the Electrical and Optical Properties of MoO ₃ /Ag/Cu/MoO ₃ Multilayer nanostructures	397-401
41	The effectiveness of lifestyle education based on Choice Theory in reducing procrastination and maladaptive or dysfunctional perfectionism	402-413
42	Investigating the Relationship of Dark Tetrad and Emotional Dysregulation in the context of Internet Gaming Disorder. Case study of a high school in Tehran	414-423
43	Synthesis of melamine formaldehyde nanocomposite with surface modified silica nanoparticles for chemical consolidation of sandstone reservoirs	424-433
44	Study of training factor for personnel in order to reduction of the H ₂ S gas leakage in Oil & Gas drilling rigs	434-441
45	Identification of Suitable Wheat Cultivars for Deficit Irrigation Conditions in West Azerbaijan (Mahabad)	442-447
46	Investigating Sustainable Design According to Sustainability Model to Achieve Less Consumption Mechanism and More Productivity from Nature	448-453
47	Comparative Analysis of Traditional Deterministic Evacuation Simulations vs. Indeterministic Cognitive Agent-Based Simulations	454-469
48	Optimizing Customer Flow in Commercial Spaces using Cognitive Agents and Machine Vision in Unreal Engine	470-479

Investigating the effect of Parasil herbal medicine on the growth performance and mortality rate of the broiler chickens

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Abstract

Plants play an important role in human and animal health, like herbal medicines. Secondary metabolites in plants often interact with essential targets in cells, such as proteins, biological membranes, or nucleic acids. In raising broiler chickens, the goal is to improve the physical performance of the poultry, such as increasing body weight and improving the Feed Conversion Ratio (FCR). However, the use of antibiotics as feed additives due to cross-resistance and multiple resistance in pathogens is dangerous. In this study, the aim is to investigate the combination of essential oils of garlic, Artemisia, and Lamiaceae under the Parasil brand to improve the performance of broiler chickens. 160 pieces of one-day-old hybrid Ras 308 broilers were prepared and transported to the breeding place. During 42 days of rearing, clinical signs, weight increase, feed conversion ratio, and mortality were investigated in different groups. During the experimental period, checking the weighing of chickens showed that in the groups treated with Parasil, the growth rate of chickens was higher than in other groups.

Keywords: Parasil, medicinal plants, broilers, Lamiaceae, Allicin

1.Introduction

Plants play an important role in human and animal health, like herbal medicines. According to the World Health Organization (WHO), herbal medicines are defined as plant-derived substances or products with therapeutic benefits from one or more plants. In general, secondary metabolites show a wide range of biological and pharmacological properties. Some plants or products isolated from them are used to treat infections and diseases[1]. Also, studies have shown that secondary metabolites in plants often interact with essential targets in cells, such as proteins, biological membranes, or nucleic acids. Some secondary metabolites act on various molecular targets, such as alkaloids on neurotransmitter receptors, others (such as phenolics and terpenoids) are less specific and attack many proteins by creating hydrogen, hydrophobic, and ionic bonds[2].

Artemisia annua plant has a hot and dry nature. Due to its natural antioxidant compounds such as phenolic compounds, flavonoids, and tannins, it has anti-inflammatory, anti-allergic, antifungal, antibacterial, and anti-spasmodic properties and facilitates blood flow. The height of the Artemisia plant reaches 6.5 to 9.84 feet and the length of the leaves of this plant reaches 20 cm. These leaves have deep and uneven cuts with sharp tips. The upper leaf surface is green and hairless to sparsely hairy, while the lower surface is white to gray and softly hairy. The upper leaves tend to be more deeply lobed than the lower ones[3].

The essential oil of this plant is most useful and effective due to its compounds such as 1,8-Cineole and thujone. Other important compounds of this plant include flavonoids, triterpenes, coumarins, adenine, amyrisin, myrcene, Squalane, nerol, vulgarin, and Artemisinin [4]. Studies have proven that the plant has antibacterial effects and is useful as an

antiseptic plant [5]. Also, it has been found that the essential oil of this plant is beneficial to the level of liver enzymes and, by reducing the damage to liver cells and liver lipids and preventing the formation of fatty liver, it reduces the level of ALT and AST enzymes in plasma [6]. This plant has an anti-coccidial effect. The mechanism is mainly the intensification of cellular endoperoxide activities, which increases free radicals, and free radicals are effective in inducing oxidative stress and alkylating proteins [7].

Garlic (*Allium sativum*) is a species of bulbous flowering plant from the *Allium* family. Its close relatives are onions, shallots, leeks, chives, and Chinese onions. Garlic belongs to the *Liliaceae* family, which are different from each other due to their pungent aroma and distinct taste. Garlic contains allicin. Allicin is a bioactive antibiotic that has antimicrobial properties. Allicin is believed to be a suitable alternative to antibiotics [8]. Research has shown that the consumption of garlic in broiler chickens infected with coccidiosis causes an increase in weight and feed consumption and a decrease in fecal oocyst output and clinical symptoms after infection [9]. In addition, garlic modulates intestinal health through its antibacterial and antiparasitic activities. Garlic treatment can also reduce oxidative stress and free radical production. Reduction of cholesterol levels and improvement of some liver and blood parameters have also been reported following the inoculation of the garlic diet [10].

Plants of the *Lamiaceae*, including lemon balm, mint, oregano, sage, hyssop, thyme, lavender, bramble, etc. In this family, interesting effective compounds such as citronolal, thymol, citral, betacaryophyllene, linalool, carvacrol, alphapinene, etc. have been found. Both the essential oil and the effective compounds of the plant species of this family can be further investigated as new drug candidates [11].

In raising broiler chickens, the goal is to improve the physical performance of the poultry, such as increasing body weight and improving the food conversion ratio. Therefore, antibiotics have been used as growth promoters. However, the use of antibiotics as feed additives because of cross-resistance and multiple resistance in pathogens is dangerous. As a result, the animal feed industry is under consumer pressure to reduce the use of antibiotics as feed additives and find alternatives to antibiotics in the diet [12]. For this reason, the demand for traditional herbal medicines and other plants has been steadily increasing during the last two decades in industrialized countries [13]. In this study, the aim is to investigate the combination of essential oils of garlic, peppermint and peppermint plants under the brand name Parasil to improve the performance of broiler chickens.

2. Materials and methods

As mentioned, there are many active metabolites in medicinal plants. The purpose of the present study is to determine and compare the effect of the Parasil compound produced by Salamat Gostar Novin Dam Makian Khorasan on broiler chickens. 160 pieces of one-day-old broiler chickens of Ras breed commercial hybrid were prepared and transported to the breeding place. The chickens were housed in standard conditions and in disinfected and clean cages; water and food were provided freely. At the age of 21 days, the chickens were randomly divided into 4 groups of 40 (each group contains 4 replications), one group as a negative control and the remaining 3 groups feeding on a mixture of *Eimeria* oocyst species (*Eimeria tenella*, *Eimeria maxima*, *Eimeria necatrix*, *Eimeria bronti*) were infected with coccidiosis. 2 groups of chickens were treated with parasil drug. Parasil was prescribed with 250 and 500 ml per 1000 liters of water for chickens. An infected group was also considered as a positive control that did not receive any drugs during the treatment period. One day after infection with oocysts, the treatment of infected chickens with the drug Parasil started and continued for 5 days. During 42 days of rearing, clinical signs, weight increase, feed conversion ratio and losses were investigated in different groups.

Table 1: Classification of groups

FirstGroup	Treatment with a 250 ml per 1000 liters of water
Second Group	Treatment with a 500 ml per 1000 liters of water
Third Group	Positive control (no drug)
Fourth Group	negative control (healthy)

3.Results and discussion

Checking the weighing of chickens during the experimental period showed that in the groups treated with Parasil, the growth rate of chickens was higher than in other groups. The highest growth rate in the treated groups was related to the second group with an average weight of 2.85 kg. As you can see in Table 2, the difference between the average weight at the end of the period in the first and second groups is low and close to each other.

Table 2: Weighted average and conversion factor at the end of the course in control and treatment groups

GROUP	First	Second	Third	Fourth
Average weight (kg)	2.8	2.85	2.5	3
Feed conversion ratio	1.9	1.97	2	1.7

The results of examining the number of casualties in different groups showed that 19 and 18 pieces were lost in the first and second groups, respectively. As mentioned in Table 3, the second group which was treated with 500 ml/1000 liters had the lowest mortality rate. Also, the reduction in mortality rate during the rearing period shows that the immune system of chickens is enhanced when treated with Parasil. In the fourth and fifth weeks, the mortality rate in the first and second groups decreased significantly, and compared to the positive control group, a 50% reduction in deaths was observed.

Table 3: The rate of casualties of the treatment and control groups during 6 consecutive weeks

Time (week)	Different groups in the experiment			
	First	Second	Third	Fourth
first week	1	1	1	2
second week	2	2	2	1
third week	3	2	2	3
fourth week	5	4	8	3
fifth week	5	5	9	2
sixth week	3	4	10	1
course	19	18	32	12

According to a study conducted in 2003 by Alçiçeko et al., 1250-day-old broiler chickens obtained from a commercial hatchery were randomly divided into five treatment groups and divided into 250 pieces each. EOC in the diet of 24, 48, or 72 mg/kg and an antibiotic in the diet of 10 mg of avilamycin were added to the basic diet. From 1 to 21 days and 1 to 42 days, the ratio of feed conversion was significantly improved by supplementation between 48 and 72 mg of EOC per kg of diet. Supplementation with more than 48 mg EOC/kg had no additional beneficial effects on body weight, feed intake, feed conversion ratio, or carcass performance. EOC, a feed additive of natural origin, may be considered a potential growth promoter in broiler production [14].

In a study conducted in 2013, the effect of oregano essential oil (*Origanum vulgare*) on the performance of broiler chickens, cecal microflora and serum antioxidant activity was investigated and compared. 180-day-old broilers were randomly divided into four groups. Group I was kept in normal control and received a basic diet. Birds of groups II, III and IV were treated with a basal diet containing 300, 600 and 1200 mg/kg treated with oregano (OEO). The inclusion of 600 mg/kg OEO in the growth diet significantly increased body weight compared to the increase with the

control group ($P < 0.05$). The supplements of 600 and 1200 mg/kg OEO significantly improved the feed conversion ratio compared to the control group in the growth period and in the entire experimental periods ($P < 0.05$) [15].

Since the use of antibiotics as growth promoters has been banned, plants or products containing plant extracts are used as alternative feed supplements in livestock production. Garlic (*Allium sativum*), turmeric (*Curcuma longa*), and cinnamon (*Cinnamomum verum*) are widely used as medicinal targets and growth promoters in animals. Research was conducted in 2012 that investigated the growth performance of birds fed with garlic, cinnamon, and turmeric powder. 240-day-old chicks were randomly assigned to 10 treatment groups, including 3 replications of 8 chicks. The experimental groups included unsupplemented (control) and formulated-supplemented diets. The total weight gain of broilers fed with 0.25% turmeric, 0.5% garlic, and 0.5% cinnamon was significantly different compared to the control group. From the results of the present study, it can be suggested that the use of garlic powder (*Allium sativum*) as a feed additive at a level of 0.5% has been proven to have a significant difference in increasing body weight and FCR compared to the control group [16].

In a study conducted in 2004, the effect of two plant extracts on the performance, digestibility, and weight of digestive organs in broiler chickens was investigated for 42 days. There were 4 treatment groups: the control group with 10 ppm of avilamycin (AB), the group treated with 200 ppm of oregano, cinnamon, and pepper extracts (EOE), and the group treated with 5000 ppm of sage, thyme, and rosemary extracts (LE). The fourth group was examined as a control group without drug administration. From 14 to 21 days of age, broilers fed the LE diet grew faster than broilers fed the control or EOE diet. Antibiotic supplements and herbal extracts improve nutrient digestibility. In the present study, both plant extracts improved the feed digestibility of broiler chickens. The effect of different additives on digestibility slightly improved the yield, but this effect was not significant [17].

4. Conclusion

Today, the importance of medicinal plants in promoting food security, economic development, and veterinary medicine in the world market is not hidden from anyone. The results of the present research showed that parasil, a medicinal plant produced by Salamat Gostar Novin Dam Makian Khorasan, had a direct effect on reducing the mortality rate of broiler chickens during the 42-day breeding period. During the experiment, in the groups treated with parasil, the average weight of chickens showed a relative increase after 6 weeks. Therefore, the drug Parasil can be very effective in the field of treatment and prevention of poultry diseases.

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Investigating the effect of herbal medicine Timosil on antibody titer and strengthening the immune system of broiler chickens

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Abstract

Antibiotics are used in the field of combating pathogenic agents and improving performance. They also have problems Including among these problems are the finding of microbial species resistant to antibiotics, their residues remaining in products, and the adverse effects of this. Therefore, the use of antibiotics in poultry breeding is prohibited in European countries, and their use has been restricted in other countries. Medical plants can improve the health and nutrition of lying hens and can be used instead of antibiotics. Medicinal plants improve feed intake, egg production, and feed conversion ratio. In this study, 360 pieces of one-day-old broiler chickens of the commercial breed Ras 308 were prepared and randomly divided into three equal groups. Chickens were vaccinated on day 7 with the injectable Newcastle and influenza vaccine (Cevac: New Flu-Kem) and on day 14 with the Lasota drinkable Newcastle vaccine. During the study, feed intake and body weight were recorded weekly. From the fourteenth day until the end of the breeding period, the first group always has the highest body weight compared to the second and control groups.

Keywords: Timosil, herbal medicines, poultry, antibody, Trachyspermum

1. Introduction

In recent years, due to the increase in the population, the increase in food consumption, and the need for animal protein sources, the poultry industry has grown significantly to meet human food needs. Industrial keeping of poultry on a large scale and intensively increases the possibility of disease. In order to reduce the incidence of diseases and to help increase growth and improve production traits, various chemicals, including antibiotics, are used in poultry farming. The use of antibiotics in the field of combating pathogenic agents also involves problems. Among these problems, we can mention the finding of microbial species resistant to antibiotics, their residues remaining in products, and the adverse effects of these substances on consumers. Therefore, the use of antibiotics in poultry breeding is prohibited in European countries, and their use has been restricted in other countries [1].

Recently, the use of medicinal plant derivatives (phytobiotics) such as plants, essential oils, and plant extracts has been suggested to achieve the above goals. Among the advantages of using medicinal plants, we can mention the simplicity of application and the absence of adverse side effects on the performance of animals, as well as the absence of harmful residues in the production products. The use of medicinal plants can increase health and improve poultry nutrition [2]. Unlike chemical drugs, which usually consist of a pure compound and are often synthetic, herbal drugs contain several

active ingredients from a single plant or a mixture of several plants, which usually act through synergistic pathways [3].

Trachyspermum is a herbaceous and annual plant with a height of 30 to 60 centimeters, belonging to the umbelliferae family, which has fruits that are gray to brown and rich in essential oil. It has anti-nausea, anti-spasm, diuretic, fever-reducing, and aromatic effects, and new scientific research conducted on it has confirmed its antiseptic, blood cholesterol-lowering, and spasm-relieving effects. Plant extracts and essential oils obtained from aromatic plants have antibacterial, antifungal, antioxidant, and anticancer properties and are able to control the growth of pathogens and the production of toxins in feed. Due to their hydrophobicity, plant essential oils are able to pass through the cell wall and mitochondria of bacteria and cause the death of the microorganism by releasing vital ions and molecules from the cell wall [4].

Thymus Vulgaris belongs to the Lamiaceae family. Thyme is a small perennial semi-evergreen ground-covered shrub rarely growing up to (40 cm) with horizontal and upright habits. Thyme leaves are very small, usually 2.5 to 5 mm long, and vary considerably in shape and hair covering depending on the variety. Thyme has one of the highest antioxidant levels among medicinal plants, which contains phenolic antioxidants such as zeaxanthin, lutein, naringin, naringenin, luteolin, and thymonin. The leaves of the thyme plant contain one of the richest sources of potassium, iron, calcium, manganese, magnesium, and selenium [5]. The purpose of this study was to investigate the effect of the mixture of essential oils of thyme, *Trachyspermum*, etc. on the amount of antibody titer and strengthening of the immune system of broiler chickens. The above product was prepared under the Timosil brand name by Salamat Goostar Novin Dam Makian Khorasan Company.

2. Materials and methods

360 pieces of one-day-old broiler chickens of a Ras breed commercial hybrid were prepared and transported to the breeding place. The chickens were kept under standard conditions in a disinfected and clean hall, and water and food were freely provided for them. The chickens were randomly divided into 3 equal groups and the order of the groups is as follows:

Table 1: Classification of groups

Group 1	Daily use of Timosil in drinking form and dosage of 250 cc per 1000 liters of water
Group 2	Daily use of Timosil in drinking form and dosage of 125 cc per 1000 liters of water
Group 3	No drug use and control group

Chickens were vaccinated on day 7 with injectable Newcastle and influenza vaccine (Cevac: New Flu-Kem) and on day 14 with Lasota drinkable Newcastle vaccine. During the study, the amount of feed consumption and body weight were recorded on a weekly basis and the amount of feed conversion factor was calculated. On the 23rd and 30th days, blood samples were taken from the wings of the chickens (two samples from each replicate) and sent to the laboratory to measure Newcastle and influenza antibody titers.

Feed conversion ratio (FCR) is the ratio of input to output. In fact, the feed conversion ratio is the number of feed units that an animal uses to produce one product unit in a growth cycle. For animals raised for meat production, FCR is the feed required to increase one kilogram of animal body weight. The feed conversion factor of a meat flock is equal to the amount of food consumed per live bird weight. A low conversion rate or feed conversion rate is better. Because it means that the chicken has produced more meat with less food consumption.

Live bird weight / amount of food consumed = broiler feed conversion factor

3. Results and discussion

The results of checking the weight of chickens in different groups showed that, at the end of the 42nd day, the highest average weight was related to group 1, which can be concluded that when the chickens were treated with 250 mm Timosil in 1000 liters of water, the growth rate was higher.

There is no significant difference between the first and third groups at the end of the experiment. On the seventh day, the second group (treatment with 125 ml per 1000 liters of water) had the highest average weight. As shown in Table 2, from the fourteenth day to the end of the rearing period, the first group always has the highest body weight compared to the second and control groups.

Table 2: Average weighting of the experimental groups in consecutive times

experimental groups	time (day)						
	1	7	14	21	28	35	42
Group 1	40	178	453	870	1408	2015	2640
Group 2	41	180	430	840	1380	1980	2590
Group 3	42	177	410	810	1350	1940	2550

In this study, all chickens were vaccinated on the seventh day with injectable Newcastle and influenza vaccine and on the fourteenth day with Lasota drinkable Newcastle vaccine. As you can see in Table 3, the antibody titer in the first group increased the most compared to the other groups after one month. Therefore, according to the increase in the antibody titer, the immune system of broiler chickens has increased during the breeding period.

Table 3: Average antibody titer in response to Newcastle vaccine (IU)

Group	Group 1	Group 2	Group 3
Day 23	2.60	2.4	2.07
Day 30	3	2.90	2.80

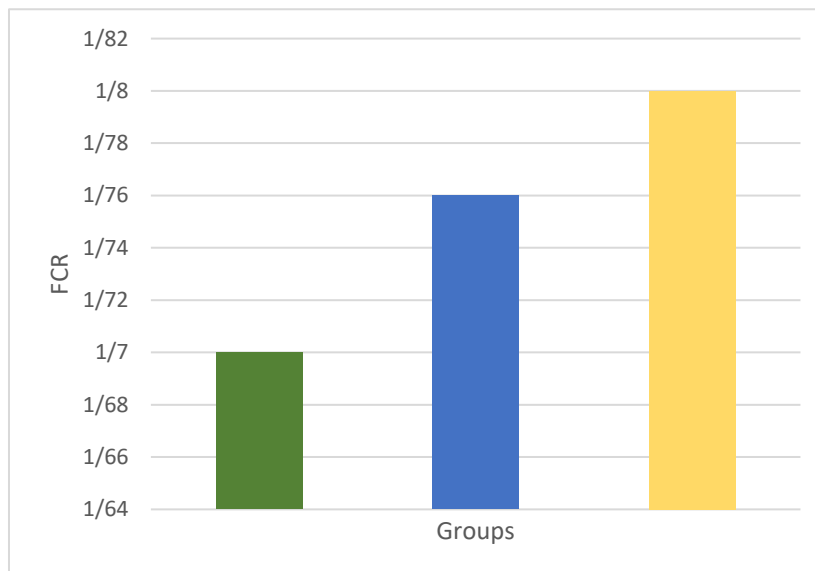


Figure 1: Feed conversion ratio in different groups during the experiment) Green = first group, blue = second group, yellow = third group)

As mentioned, the feed conversion ratio (FCR) of a broiler flock is equal to the amount of feed consumed per live bird weight. A low conversion rate or feed conversion rate is better. Because it means that the chicken has produced more meat with less food consumption.

According to the study that was conducted, the effects of feeding a mixture of sorbic acid, fumaric acid and, thymol (EOA) on growth performance, digestive functions and, immunity of broiler chickens were investigated. A total of 640 one-day-old chicks with the same body weight (41.8 ± 0.6 g) were randomly divided into 4 food treatment groups including 10 replicates with 16 birds in each replicate and were fed on the basic diet until 42 days old (CON) or diets containing 0.15 g/kg anramycin during the growing period (AG), 0.30 g/kg EOA during the growing period (EG), or 0.30 g/kg EOA during the finishing period (EF). On day 42, the feed conversion ratio for birds in the EG group decreased compared to other groups ($P < 0.05$). Birds of the EG group showed higher villi of duodenum and jejunum and muscular layers of duodenum and ileum compared to birds of the CON group ($P < 0.05$). As a result, the results show that EOA can be effectively used in the diets of broiler chickens, especially in the growing stage, by improving intestinal morphology and increasing the activity of digestive enzymes[6].

In 2015, a study was conducted by Tahami et al. In this experiment, the effect of using a mixture of medicinal plant extracts compared to an oxytetracycline antibiotic on serum enzymes and the body weight of 308 broiler chickens was done. The experimental treatments included treatments containing antibiotics and a 50, 100, and 200 mg/kg diet of a mixture of pepper, cinnamon, and oregano medicinal plant extracts. The results showed that the feed consumption in 1 and 10 days and the feed conversion ratio decreased significantly under the influence of the addition of 100 mg/kg of plant extracts [7].

In research to compare the effects of a growth-promoting antibiotic (flavomycin) and two natural plant feed additives (garlic and thyme) in wheat-based diets on growth performance, carcass parameters were conducted. Cholesterol concentration, intestinal characteristics and the amount of dry matter in the feces of broiler chickens. A total of 112 one-day-old male broiler chickens were randomly divided into eight groups containing 14 chickens and raised from 1 to 42 days old. The control group received the basic diet of wheat and soybean meal. In the treatment groups, the basal diet was supplemented with one of the following: antibiotic, thyme, garlic, enzyme, antibiotic plus enzyme, thyme plus enzyme, or garlic plus enzyme. During the 42-day growth period, there was no significant difference in body weight gain, feed consumption and feed conversion ratio of broiler chickens between diet treatments. Broilers receiving antibiotic-supplemented diets had significantly lower total numbers of aerobic bacteria in the small intestine compared to other dietary treatments. Combined antibiotic and enzyme supplementation resulted in a significant reduction of *E. coli* concentrations in the small intestine compared to basal diet and other nutritional treatments [8].

In Sadeghi et al.'s study in 2012, the effects of replacing drinking water with herbal teas on performance, relative weight of internal organs, hematocrit and immune response to Newcastle virus in broilers were investigated. A total of 540 male broiler chickens (308 heads) were divided into five groups corresponding to four different treatments and one control group. The experimental treatments included infusion (5 g/L) of cinnamon, thyme and turmeric in equal proportions instead of drinking water. The results showed that the infusions of most plants caused a significant decrease in live body weight compared to the control group at the age of 21 days. The mixed treatment significantly reduced the relative weight of the carcass compared to the control group [9].

4. Conclusion

According to the documentation presented in this study, the use of the drug Timosil with a dose of 250 cc per 1000 liters of water improves weight gain, improves the conversion rate and strengthens the immune system of broiler chickens. During the research, due to the increase in antibody titer, the immune system of broiler chickens increased

during the 42-day period. Also, from the 14th day until the end of the breeding period, the first group (daily use of Timosil in drinking form and dosage of 250 cc per 1000 liters of water) always has the highest body weight compared to the second group and control.

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Examining the effect of exosomes on fertility

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ABSTRACT

Exosomal nanoparticles (exosomes or nanovesicles) are biogenic membrane vesicles that are secreted by different types of cells and show the conservative mechanism of intercellular and interspecies communication in proto and eukaryotic organisms. By transporting specific proteins, nucleic acids and low molecular weight metabolites, exosomes play a role in regulating growth processes, activating the immune system and creating a protective response against stress. Recently, plant nanovesicles have attracted a lot of attention in the field of biomedicine due to their economic and cost-effective production source. As a natural transport system, plant exosomes are a promising platform in biomedicine to deliver molecules of endogenous and exogenous origin. The present study presents the biogenesis of exosomes and their composition, their loading mechanisms with different therapeutic compounds, which are the determining factors for their possible practical use, and also their effect on fertility.

Keywords: exosome, fertility, nanovesicle.

1.INTRODUCTION

Interest in intercellular communication has increased in recent years with the increasing awareness of the complexity of its participation in various physiological processes, including the regulation of cell proliferation, differentiation, gametogenesis, embryogenesis and growth. In particular, the identification of extracellular vesicles (EVs) as new mediators of intercellular communication has refocused research efforts in this field. Extracellular vesicles, including exosomes, are membrane-bound nanovesicles that contain proteins, lipids, and nucleic acids (microRNA and mRNA) that play a role in cell communication [1]. A wide variety of cells release extracellular vesicles under physiological and pathological conditions. Extracellular vesicles play an important role in multiple biological interactions, including reproduction, and act as potential theranostic candidates for normal and abnormal conditions [2]. Unlike other extracellular vesicles, exosomes are released from cells through exocytosis. Traditionally, intercellular communication involves three mechanisms: contact-dependent signaling through membrane-bound signaling molecules (receptors) or gap junctions, short-range paracrine signaling through secreted soluble molecules such as cytokines and chemokines, and long-range Is vivocrine signaling. Secreted hormones Recent studies have discovered the existence of extracellular vesicles that are released by cells in the extracellular environment and can be used as carriers to transfer proteins, lipids and RNAs between cells. ▯ act locally (autocrine and paracrine) and remotely [3]. Vesicles are released by a wide range of cell types in normal and pathological conditions. Their cargoes may play key roles in multiple aspects

of biology, including reproduction, as candidate biomarkers of health and disease, and as potential targets for therapeutic interventions [4].

Exosomes are like a snapshot of the cells of origin, and the variability of the secreting cell is reflected in exosome compositions [126]. When these exosomes are taken by the target cells, they transfer their cargo, which includes proteins [5], miRNA [6] and mRNA [7], to the target cells. This cargo may participate in energy pathways, protein metabolism and maintenance of receptor cells. Therefore, exosomes cause different epigenetic and phenotypic changes on the recipient cells, which affect the survival, tolerance to external factors and regeneration capabilities of their target cells [8]. It has also been found that exosomes perform important bioactive functions such as sperm maturation, capacitation, acrosome reaction and fertilization [9]. In the following, we will examine the effect of exosomes on fertility.

Improve sperm quality

Structural integrity of sperm is essential for proper function and egg fertilization. Structures including the plasma membrane (physiological barrier [9]), acrosome (sperm penetration), and chromatin (embryo quality [10]) influence gamete interactions and embryonic development. Damage to these structures can lead to fertilization failure. Exosomes can transport spermadins (AWN and porcine seminal protein, PSP-1) to the sperm membrane, which can maintain sperm function by inhibiting premature capacitation (decapacitation) during long-term liquid storage. help [9]. Similarly, mesenchymal stem cell-derived exosomes increased the fraction of sperm with an intact acrosome and expression of transcripts related to plasma membrane repair (ANX 1, FN 1, and DYSF) and chromatin materials. (H3 and HMGB 1) in frozen/thawed sperm [8].

In addition, higher concentration of exosomes isolated from seminal plasma significantly reduced the percentage of capacitated spermatozoa after artificial capacitation using 3 mg/ml BSA, capacitation is a physiological process that enables sperm to Fertilize the eggs. Naturally, capacitation occurs during the transfer of sperm through the uterus and oviduct. Sperm storage in laboratory conditions requires inhibition of premature capacitation to maintain sperm survival [9].

Oxidative damage of sperm

Oxidative stress is one of the main causes of low sperm fertility after thawing [11]. the increase in antioxidant activity in frozen/thawed mouse sperms treated with exosomes during freezing, a decrease in mitochondrial ROS modulating gene expression (ROMO1) in sperms treated with exosomes has been reported [8]. In addition, increased total antioxidant capacity activity and decreased malondialdehyde content when the diluents were supplemented with seminal plasma exosomes, has shown. It is assumed that the increased antioxidant capacity of sperm is either due to the horizontal transfer of antioxidants and other factors including mRNA and protein from exosomes or due to the modified hydrophobicity of the membrane [9].

Using natural or synthetic nanoparticles and nanovesicles such as exosomes and liposomes to improve sperm freezing. Compared with metals or plant extracts, nanoparticles with significant effects mainly act as antioxidants. The functional molecules inside exosomes, such as miRNA, mRNA and proteins, are involved in the correct implementation of a wide range of physiological interactions that can help solve the problems related to male gamete fertility. Liposomes with the contents of phospholipids and lipid chains can replace damaged fat skeletons of frozen/thawed sperms. Treatment of spermatozoa with exosomes improved the efficiency of cryopreservation methods. However, further in vivo and fertility studies are necessary to investigate the effect of exosome treatment on sperm function. Since liposomes are currently available as a commercial product for sperm freezing, nanoparticles and nanoformulations as well as extracellular vesicles and exosomes derived from reproductive tract or stem cells should be Adhere to appropriate manufacturing practices, quality control measures, and safety and efficacy protocols for commercial purposes [12].

In cows, oviduct-derived extracellular vesicles significantly stimulated the acrosome reaction by increasing protein tyrosine phosphorylation levels and increasing intracellular calcium levels in frozen/thawed spermatozoa [13]. In wildlife animals, oviduct-derived extracellular vesicles showed improvement in sperm motility and acrosome integrity and prevented premature acrosome reaction after thawing [14].

Embryo growth and quality

The first stages of bovine embryo development occur in the oviduct, where the embryo spends about 4 days [15]. The oviduct is an active organ that maintains and adjusts the environment for sperm capacity, mature egg transfer and fertilization, and early embryonic development [16]. The embryo undergoes epigenetic changes in the oviduct, which is responsible for further growth, implantation, and phenotype after birth [17].

The environment of the fallopian tube can support the development of the embryo until the blastocyst stage in a wide range of species after the transfer between species [18]. The signal exchange between the embryo and the oviduct is significant, although the molecular mechanisms involved in this embryo-maternal communication are currently largely unknown [19]. The epithelium of the oviduct consists of ciliated and secretory cells that secrete proteins and other factors that help the development of the early embryo [20]. Bovine ductal epithelial cells participate in close contact with gametes and embryos during fertilization and early embryo development and are considered the most suitable in vitro model to study early maternal-fetal interactions [21]. Recent studies have shown that membrane-bound vesicles, collectively called extracellular vesicles, released by somatic cells contain bioactive molecules (i.e., proteins and RNA, mRNA, miRNAs, and lipids, and in some body fluids [22]. It has been shown that extracellular vesicles can transfer functional RNAs horizontally to other cells [23]. Therefore, extracellular vesicles are an important tool in intercellular communication that play a key role in the regulation of several physiological and pathological processes [24]. In reproduction, there are secreted vesicles in follicular fluid [25], endometrial environment [26] and seminal plasma [27].

A research to evaluate the effect of extracellular vesicles derived from bovine ovarian tube epithelial cells on the growth capacity of bovine zygotes, the quality of embryos produced in laboratory conditions and possible zygotes cultured under specific conditions. Isolated vesicles improved embryo quality and induced cold protection in laboratory cultures. This is the first study in which extracellular vesicles have been isolated from bovine fallopian tube epithelial cells, characterized morphologically and successfully used in in vitro embryo culture as a substitute for serum to improve the quality of produced embryos [28]. Adding fetal bovine serum to the culture medium accelerates the kinetics of fetal growth and increases the number of fetal cells, the serum also contains extracellular vesicles with an unknown function in the growth and quality of the embryo. Extracellular vesicles from fetal calf serum may be at least partially responsible for its consequences in short-term and long-term fetal development. Importantly, our history also shows that the addition of bovine fallopian tube epithelial cell extracellular vesicles can compensate for the deleterious effects of fetal calf serum extracellular vesicles. Therefore, the results showed that vesicles have a positive effect on the quality of cow embryos produced in laboratory conditions, and show that they have a determining function in the connection between the fallopian tube and the embryo in the early stages of development [29].

As a result, by trying to mimic the intercellular communication between the fallopian tube tissue and the embryo, evidence has been presented that extracellular vesicles isolated from the conditioned medium of a cultured bovine fallopian tube epithelial cell monolayer improves embryo quality and protects in It induces cold in laboratory cultures [28].

Two-way communication between embryo and mother

Communication between the embryo and its environment is important for proper development [30]. The communication between the embryo and the mother is two-way and starts in the early stages of development in the oviduct. This connection is necessary for implantation and full development of the embryo in the uterus [31]. On the other hand, the role that extracellular vesicles play in fetal-maternal communication has been described, suggesting

that their cargo contains molecules that can modulate fetal growth and implantation [32]. In addition, the quality of embryos affects the ability of extracellular vesicles to induce maternal responses during pregnancy detection [33].

It has been shown that signals induced by embryos produced in vitro in endometrial cells cause an ineffective endometrial response [34]. This inappropriate interaction can be the reason for the low implantation rate observed during embryo production in laboratory conditions. The content of extracellular vesicles is influenced by their origin, whether they are produced by fallopian tube cells in vivo or in vitro. This, in turn, compromises the effect of these extracellular vesicles on embryonic development [35]. Similarly, the origin of the embryo (eg, in vivo or in vitro) changes the characteristics of the embryonic extracellular vesicle population, including concentration, average size, and molecular content. Thus, changes caused by in vitro systems are also reflected in the ability of extracellular vesicles secreted by the embryo and the maternal environment to mediate fetal-maternal interaction [36].

During the pre-implantation period, embryos secrete extracellular vesicles containing interferon tau (IFNT), which are then internalized by endometrial cells. This internalization leads to the expression of interferon-stimulated genes (ISGs) in a laboratory model [37]. Extracellular vesicles have become important in the communication between embryo and mother in the early stages of development. The aim of the study [38] was to investigate the effect of a laboratory system on early fetal-maternal two-way communication mediated by extracellular vesicles. For this purpose, two experiments were performed: one to evaluate the effect of fetal extracellular vesicles on maternal cells and the second to determine the effect of maternal extracellular vesicles on early embryo development. Fetal extracellular vesicles were added to the medium of bovine endometrial cells cultured in vitro to evaluate their effect on the expression pattern of genes related to endometrial function and response to tau interferon. The results of this work help to confirm the role of extracellular vesicles in the interaction between embryo and mother in the early stages of development. In addition, evidence is provided for the differential effect of extracellular vesicles based on their origin (in vivo or in vitro). Extracellular vesicles released by in vitro embryos had a stronger effect on modifying gene expression in endometrial cells. This effect may be due to the different loads of embryonic extracellular vesicles, which can reflect the difference between embryos produced in vivo and embryos produced in laboratory conditions. The results of this work help to confirm the role of extracellular vesicles in the interaction between embryo and mother in the early stages of development. In addition, evidence has been presented regarding the differential effect of extracellular vesicles based on their origin (in vivo or in vitro). Extracellular vesicles released by in vitro embryos had a stronger effect on modifying gene expression in endometrial cells. This effect may be due to the different loads of embryonic extracellular vesicles, which can reflect the difference between embryos produced in vivo and embryos produced in laboratory conditions. These differences probably explain the changes observed by other researchers during in vivo development. On the other hand, the beneficial effect of extracellular vesicles derived from uterine fluid on embryonic development supports the idea that the culture medium is not yet optimized for accurate reproduction of maternal conditions [38].

Embryo implantation

Embryo implantation is the rate-limiting step for successful pregnancy and requires a complex interaction between the embryo and the endometrium. Extracellular vesicles are membrane-enclosed and nano-sized structures that are produced by cells to mediate cell-to-cell communication and modulate a diverse set of biological processes, the involvement of extracellular vesicles in the process of embryo implantation and diseases. The endometrium was examined. Extracellular vesicles have been isolated from uterine fluid, cultured endometrial epithelial/stromal cells, and trophoblastic cells. Extracellular vesicles derived from endometrial epithelial and stromal/decidual cells are internalized by trophoblast cells and regulate a diverse set of genes involved in adhesion, invasion and migration. Conversely, embryo-derived extracellular vesicles and their cargo are internalized by endometrial epithelial and immune cells for biosensing and immune modulation required for successful implantation. Extracellular vesicles have also been shown to be involved in infertility, recurrent implantation failure, endometriosis, endometritis, and endometrial cancer [39].

CONCLUSION

In the last two decades, there has been an exponential increase in the number of studies devoted to the biological properties of nanovesicles (the most important carriers of biological information). The endogenous nature of nanovesicle formation is their natural and unique advantage for intercellular communication and a wide range of biological activities. Nanovesicles can be selectively taken up by nearby and distant cells and programmed with their biologically active contents, mainly due to proteins and ribonucleic acids.

The orderly formation of nanovesicles, the possibility of imparting specific biological activity and cellular targeting to them, as well as their scale production potential, are of great interest for practical use. In addition to the fact that the use of human exosomes in some cases is equal to therapeutic stem cells in terms of effectiveness, there are currently a number of successful examples of the medical use of herbal nanovesicles. Further studies are needed to standardize protocols for their isolation and characterization, develop efficient storage and loading technologies, and improve targeting for specific cell types.

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Investigating the effect of vigor stimulator on the morphological properties and growth factors of tomato plants

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Abstract:

Vigor stimulator is a homogeneous powder mixture of humic acid, fulvic acid and seaweed, which has a significant effect on improving germination, optimization and uniformity of flowering. It also helps in the production of pollen and fruit set and causes the development of leaves and increases the greenness of the plant and is effective in increasing the absorption of nutrients. The aim of this research was to investigate the effect of vigor stimulator fertilizer on the morphological characteristics of tomato plants, including plant height, stem diameter, number of flowers, leaf cross-sectional area and chlorophyll in different stages. This fertilizer has been very effective in strengthening the root, stem, flowering and cross section of the leaf. Fulvic acid creates an organic coating around macro and micro nutrients, which is similar to plant tissues and easily penetrates into them. It improves the absorption of nutrients and thus increases the amount of flowering. In this research, the amount of flowering increased by 18.7 meters with the use of growth stimulator fertilizer. *Ascophyllosum nodosum* seaweed is rich in active compounds that have the same activity as hormones. It has auxin and cytokinin. Hence, it stimulates cell division and provides hormonal balance in the plant tissue. It also increases the activity of photosynthesis in the plant. In addition to its good chelating properties, humic acid flows well in different plant tissues and easily enters the roots, stems and leaves and transfers micronutrients from the plant surface to the plant tissue. Therefore, it is a key ingredient in many foliar fertilizers. In this research, the cross-sectional area of the leaf has increased significantly compared to the control sample and reached from 28.4 meters to 119.2 meters. Due to the presence of natural ingredients used in growth stimulating fertilizer, it helps to produce healthier products with better taste.

Keywords: Humic acid, Fulvic acid, Seaweed, Growth promoter, Chlorophyll

1. Introduction:

Any compound that increases the growth rate in plants is called growth stimulating fertilizer. These fertilizers are produced for the growth of different parts of the plant and are generally categorized as follows: vegetative growth stimulator, root growth stimulator, reproductive growth stimulator [1]. In growth stimulating fertilizers, the fertility of plants increases, the degree of dehydration of the plant is controlled, the strength of the plant against cold and heat increases, the plant is stimulated to germinate, the nutrients that are in the soil are more penetrate into the plant, the amount of leaves of the plant increases, the level of resistance of plants against diseases is well maintained, the growth stimulating fertilizer helps the plant to have stronger roots, the best rooting stimulating fertilizer prevents The plant wilts, the growth stimulating fertilizer makes the plant regularly yield and produce fruit [2]. Growth stimulating fertilizer, by increasing the growth of the plant's aerial organs (leaves, flowers, buds), helping to strengthen the plant's immune system, increasing the plant's metabolism and making the plant resistant to environmental stresses (cold and heat) and increasing the exchange rate of various elements and The compounds in the plant help it grow better. [3]

Fertilizers that stimulate the growth of plants provide nutrients in an absorbable form. These elements include major mineral elements such as nitrogen (N), phosphorus (P) and potassium (K), which are known as major nutrients. But

in addition to these elements, growth promoting fertilizer may contain other rare elements such as zinc (Zn), iron (Fe), manganese (Mn), copper (Cu) and molybdenum (Mo). Providing sufficient sources of these nutrients to plants stimulates growth, better germination, development of the root system and increase in yield.

Growth promoting fertilizers can regulate the growth processes of plants. Some growth promoting fertilizers include plant hormones such as auxins, gibberellins and cytokinin. These hormones stimulate the growth of plants by regulating cell activity, dividing and increasing cells, regulating germination and tissue development.

Growth promoting fertilizers can stimulate germination and root growth. These fertilizers can facilitate better plant nutrition by creating suitable environmental conditions for the growth of roots. Also, strengthening the roots helps the plants to use the water resources and nutrients in the soil more effectively.

Growth promoting fertilizers can increase the resistance of plants against various stresses such as drought, salinity, cold and diseases. These fertilizers may contain elements that strengthen the defense system of plants and increase their resistance against environmental stress.

Growth promoting fertilizer can regulate the physiological activities of plants. These fertilizers may facilitate the improvement of absorption and use of light by plants, the regulation of water balance, the increase of enzyme activity, and the regulation of the activity of the respiratory and photosynthetic systems of plants [4].

Humic acid is recommended to increase plant phosphorus uptake because it is able to compete with phosphorus for binding to soil absorption networks. Commercial humic acid, mainly obtained from lignite coal, is widely used to improve soil and crop growth. Humic acid used in soil obtained from Leonardite and lignite coal has generally been successful in increasing the yield of potato, wheat, lettuce, tomato and corn. Humic acid is the result of decomposition of organic matter that directly or indirectly supports plant growth and performance in acidic soil. It causes an increase in pH in the soil. Increasing soil pH due to an increase in CEC of the soil increases the buffering capacity and soil microorganisms, increasing the availability of phosphorus, nitrogen and other coarse nutrients in the soil [5].

Tomatoes need a lot of water and high environmental temperature to grow, and the amount of light is effective on the production and quality of the fruit [6]. He pointed out transgenics and the use of fertilizers that stimulate plant growth. From an economic point of view, tomatoes are considered the second most valuable vegetable after potatoes, and in terms of per capita consumption, they are placed after them. According to the published statistics, the production of tomatoes has increased in recent years, so that in 2008 the total world production was 140 million tons and in 2018 it reached more than 180 million tons [FAO 2018].

This research was carried out in order to determine the effect of growth stimulating fertilizer on the morphological characteristics of tomato plants.

2. Materials and methods

Greenhouse test:

In order to investigate the effect of flowering growth stimulant on tomato plant, this research was conducted as a greenhouse experiment in treatment and control mode. Things such as the comparison of plant height, stem diameter, leaf cross-sectional area, number of flowers and chlorophyll in control and treatment were investigated on five plants of tomato variety 4129 in a greenhouse in Kian Dasht. Experiments were conducted in three periods through foliar spraying with the use of 30 grams of flowering growth stimulating fertilizer and without the use of flowering growth stimulating fertilizer as a control. The analysis of the compounds used in this fertilizer is shown in Table 1.

Analysis table					
Total organic matter	Soluble potassium	Folic acid	Seaweed	Humic acid	Elements
%51	%6	%5	%25.6	%25.6	Weight percent

Table 1. product Analysis

Measurement of seedling morphology traits:

Plant height: Plant height was measured using a meter with an accuracy of 0.01 meters.

Stem diameter: The diameter of the stem was measured at a distance of one centimeter from the connection to the root by a digital caliper with an accuracy of 0.01 mm.

Number of leaves: The number of leaves per plant was counted and its average was calculated.

Number of leaves: The number of leaves per plant was counted and its average was calculated.

Leaf cross-sectional area: Leaf cross-sectional area was measured through Image J software.

Calculation of chlorophyll:

Chlorophyll content of leaves was measured using dimethyl sulfoxide method. First, 0.2 grams of fresh leaf pieces without leaf veins were placed inside the test tube, then 7 ml of dimethyl sulfoxide was poured on them and placed in the incubator for 30 minutes at a temperature of 60 degrees Celsius. Then, the smooth extract and the leaf tissues inside the Erlen were discarded. By adding dimethyl sulfoxide, the volume of the extract was increased to 10 ml. Finally, with the help of spectrophotometer, the absorption of the extracts was read at wavelengths of 663, 645, and 470 nm. DMSO was used as a device blank. The chlorophyll content of the samples was reported as milligrams per gram of fresh leaf weight and was calculated and measured using the formulas introduced by Arnon [7].

Results and discussion:

This research was conducted in order to investigate the growth stimulating fertilizer on tomato plant during a period of eleven weeks. This fertilizer was applied as a foliar spray with a concentration of 30 grams on tomato plants and its growth parameters were compared with the control. The results showed that the tomato plants treated with the flowering growth stimulant showed significant growth compared to the control group. The treated plant increased plant height, leaf size, a greater number of young flowers, more flowering and biomass accumulation. They showed more generality. Plant growth stimulant contains bioactive compounds such as amino acids, vitamins and plant hormones, which are known to increase plant growth and development. As shown by the increase in plant height, larger leaf size and more bioaccumulation, this product is attributed to the stimulating ability to promote the absorption of nutrients, improve nutrient absorption and stimulate the plant's metabolism and cell division, and increase the height of the plant, larger leaf size and Biomass accumulation increases.

Performance:

VIGOR STIMULATOR, a homogeneous powder mixture of humic acid and *Ascophyllosum nodosum* seaweed, is a functional product and a strong growth stimulator designed for crops, gardens and ornamental flowers during the growth period from the time of root and leaf formation to flowering and fruiting. . This product has significant and beneficial effects on plants, such as: a significant increase in flowering, an increase in the number and size of fruit that stimulates root growth, and has positive effects on photosynthesis. ... yes, it helps to increase the efficiency and quality of the product.

The application of growth stimulating fertilizer on different products is shown in Table 2.

Application table				
Use after transplantation	Greenhouse plants	Vegetables and summer herbs	Garden, agricultural and industrial products	product
100 grams in 300 liters of water	25 to 50 grams in 100 to 200 liters of water	100 grams per hectare in 100 liters of water	100 to 150 grams per hectare in 100 liters of water	Consumption in irrigation water
–	25 to 50 grams per 200 liters of water	100 grams per hectare in 200 liters of water	100 to 150 grams per hectare in 200 liters of water	The amount of leaf consumption

Table 2. The table of the consumption of growth stimulating fertilizer in different products

The effect of growth stimulating fertilizer on plant height:

Ascophyllosum nodosum seaweed is rich in active compounds that have the same activity as auxin and cytokinin hormones. Hence, it stimulates cell division and provides hormonal balance in the plant tissue. Also, humic acid and fulvic acid have a very effective effect on plant height. Due to its good chelating effect, humic acid improves the soil and increases the absorption of nutrients. In addition, vigor stimulator fertilizer increased lateral growth, which led to thicker and fuller backs of tomato plants compared to the control group. By measuring the diameter of the plant and its height at certain time intervals, the growth stimulating fertilizer showed a significant increase in its height and diameter compared to the control plants, and the length of the stem in the plant became longer. The height of the plant in the first stage in the treatment sample was 86 meters and after three stages of foliar spraying with growth-stimulating fertilizer, it reached 138 meters, which has increased more than the control sample without the use of growth-stimulating fertilizer (Figures 1 and 2). In the research of Amini Fard and Colleagues, the effect of fulvic acid and humic acid on coriander plant was done and the results showed that these two substances had a significant effect on the height of the plant compared to the control [8].

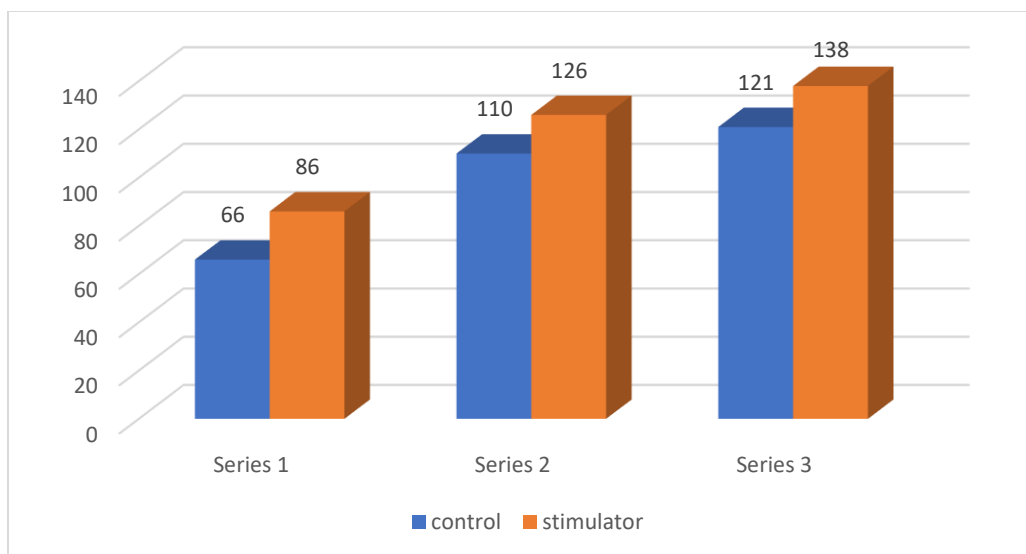


Figure 1. Comparison of plant height changes using growth stimulating fertilizer and control



Figure 2

The effect of growth stimulating fertilizer on stem diameter:

In addition to the effect of humic acid and fulvic acid on plant height, these two substances have a very effective effect on plant diameter. The results showed that the fruit diameter increased from 11.8 in the first stage to 12.8 in the third stage (Figure 3).

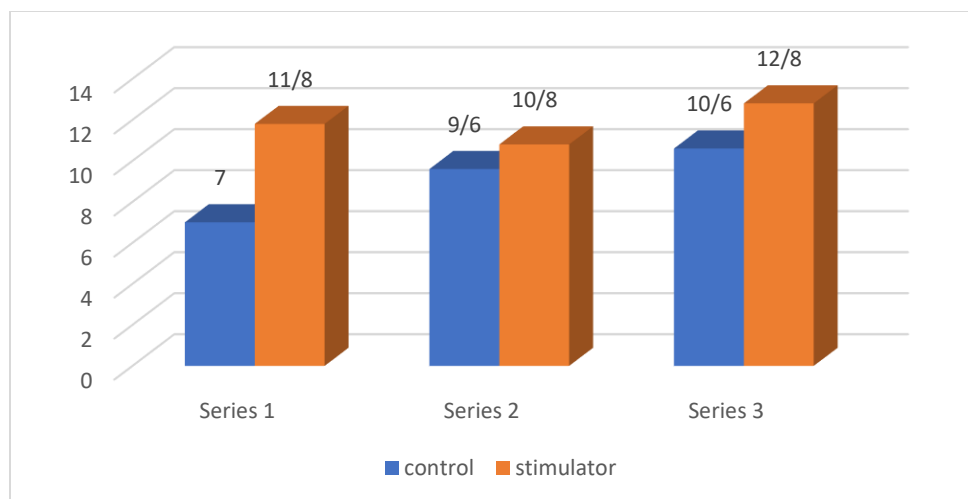


Figure 3. Effect of growth stimulant on flower number

Fulvic acid creates an organic coating around macro and micro nutrients, which is similar to plant tissues and easily penetrates into them. It improves the absorption of nutrients, thereby increasing the amount of flowering. Humic acid, as a fertilizer, guarantees the freshness and health of the plant and also causes the plant to take root. It also has a great role in improving the soil and increasing plant productivity. Humic acid increases the absorption of nitrogen, which increases the vegetative growth of garden or agricultural plants, and also increases the quality of the produced product due to the improvement of the absorption of protein and nucleic acids from the soil. The increase in the number of flowers by using growth stimulating fertilizer is shown in Figure 4.

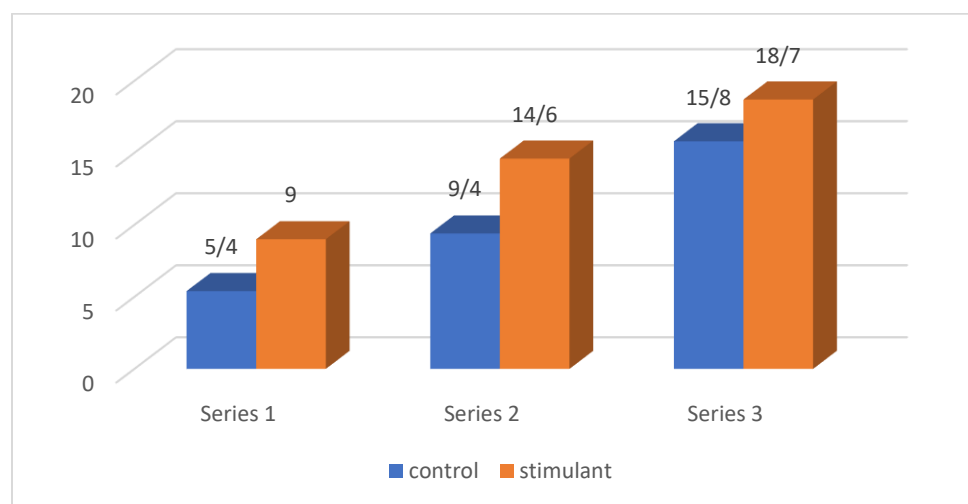


Figure 4. Comparison of the number of flowers in different stages with and without the use of growth stimulating fertilizer

The effect of growth stimulants on the cross-sectional area of leaves and chlorophyll:

Humic acid also strengthens the content of chlorophyll and mesophyll and stimulates photosynthetic activity. In addition to its good chelating effects, humic acid moves easily in the plant tissues and easily enters the roots, stems and leaves and transfers micronutrients from the plant surface to the tissues. Therefore, this compound is a key element in many foliar fertilizers. Humic acid includes a wide range of organic-mineral compounds such as: amino acid, peptides, phenols and neochloroic acids. By adding humic acid to the soil, it is possible to improve the function of chlorophyll, which is the cause of greenness and plant leaves. In this research, the level of chlorophyll is obtained was

49.66, which has increased more than the control without the use of stimulatory fertilizer (Figure 5). Also, by adding growth stimulatory fertilizer to the tomato plant, the cross-sectional area of the leaf reached from 28.4m to 119.2m, which The leaves have increased significantly (Figure 6). In the research of Saber Heydari et al., it has been shown that the use of humic acid algae has been very effective in absorbing elements through the leaves [9]. [Also, the use of humic acid in tomatoes increased the amount of chlorophyll]10.

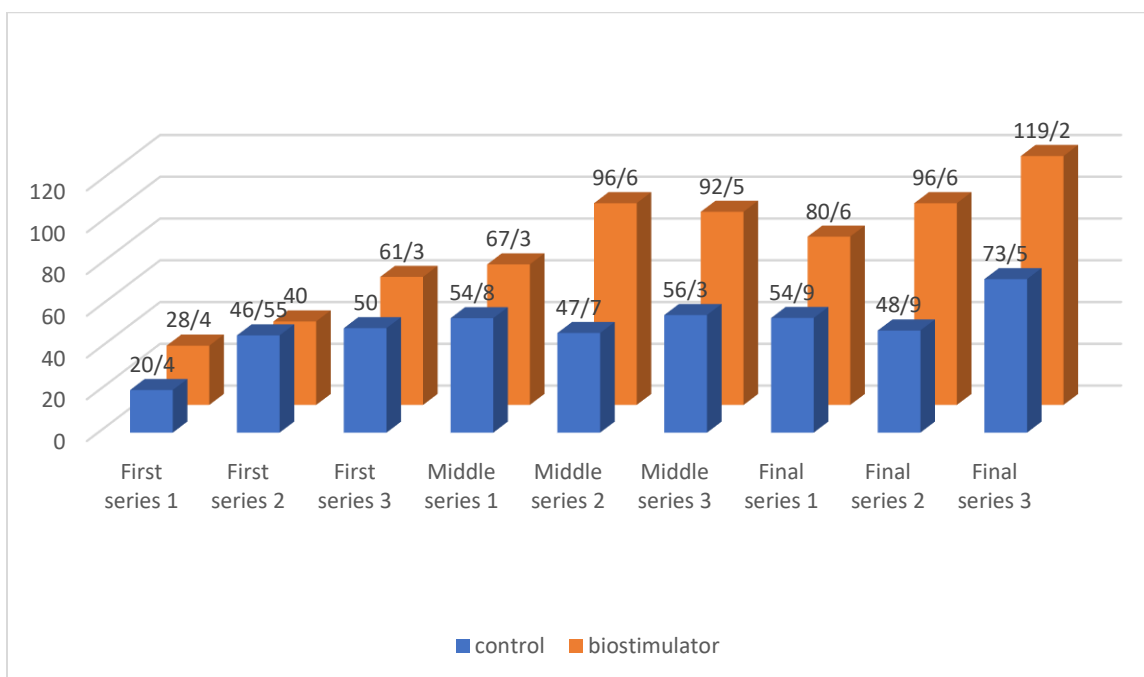


Figure 5. Comparison of leaf cross section

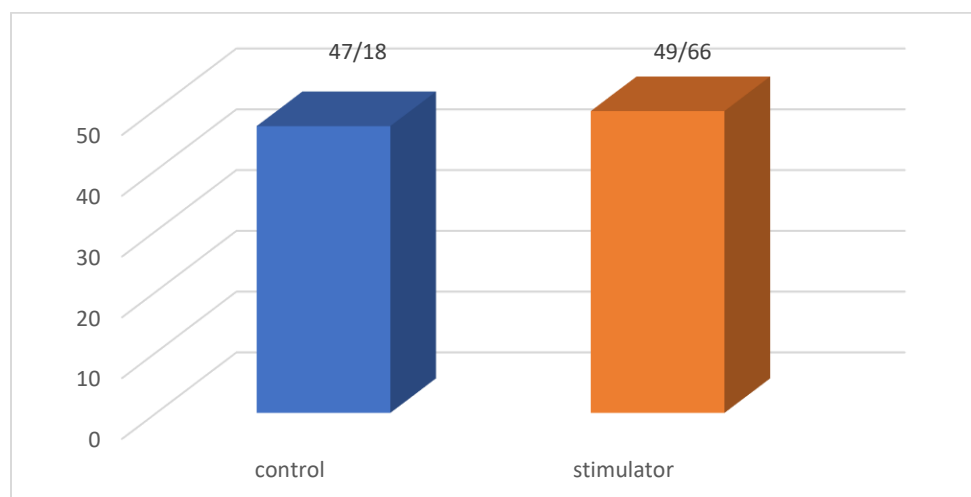


Figure 6. Measurement of total chlorophyll

Conclusion:

Growth stimulant fertilizer that contains compounds such as humic acid, fulvic acid and seaweed, which has had very effective effects on morphological traits such as stem diameter, plant height, number of flowers, leaf cross-section and chlorophyll, and has caused a significant increase in them. . Due to the presence of humic acid, which strengthens the content of chlorophyll and mesophyll, as well as seaweed, which has the same activity as the hormone auxin and cytokinin, it causes cell growth and strengthening.

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The Effect of Drought Stress on the Performance of Wheat Grain Crops

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Abstract

The aim of this research is to study the effect of drought stress on the performance of wheat grain crops. To examine the impact of end-season drought stress on yield, yield components, and stress evaluation indices in wheat, two separate experiments were conducted using a randomized complete block design with three replications at the Mahabad Agricultural Research Center during the 98-99 (2010-2011) agricultural year. For the application of drought stress, irrigation was stopped after 50% of spike emergence until harvest, whereas, under normal conditions, irrigation continued until the end of the growth period. Traits such as grain yield, number of grains per spike, thousand-grain weight, spike length, peduncle length, and plant height were measured. The response of wheat lines was different under the two conditions. Drought stress led to a reduction in yield and yield components. Furthermore, the indices MP, GMP, HARM, SSI, TOL, and STI were evaluated. Results showed that lines 11, 13, 15, 18, and 19 were the most resistant under both optimal and stress conditions, while lines 2, 5, and 7 performed well under optimal conditions. MP, GMP, HARM, and STI indices showed a high correlation with grain yield under both irrigation and stress conditions, indicating that these indices are suitable for both conditions.

Keywords: Drought stress, performance, wheat

Introduction

Drought stress is a natural problem that commonly occurs in areas with water scarcity and high evaporation. When agriculture and the cultivation of grain crops like wheat face drought stress, the performance and yield of these crops can be affected. Drought stress can significantly reduce the water needed for plant growth and development, leading to smaller plant size, fewer branches, and fewer formed flowers. Drought can negatively impact the production of wheat's aerial parts, such as reducing the number and size of spikes, which in turn leads to reduced grain production and ultimately lower yield. Additionally, drought can decrease grain quality by reducing grain size, oil content, protein content, and altering nutritional characteristics. Drought can damage the roots and stems of plants, reducing their ability to absorb water and nutrients, resulting in decreased crop performance. Wheat plants are differently sensitive to drought and sunlight at various stages of their growth and development. They may be more sensitive to drought during critical stages such as flowering and grain formation, impacting crop yield.

Overall, drought stress can reduce the yield and performance of wheat grain crops. Additionally, drought stress may increase the chemical load in the soil, leading to reduced soil productivity and quality. To mitigate the effects of drought stress, appropriate irrigation systems, drought-resistant varieties, water resource management, and optimal use of organic materials and fertilizers can be beneficial. Further research on developing drought-resistant plants and drought management methods can improve wheat grain crop performance under drought conditions.

Theoretical Framework and Research Background(Theoretical and literature review) :

Drought stress is one of the important factors affecting the performance of wheat grain crops. It refers to water scarcity in the soil or excessive water use by plants, which can impact the growth and yield of wheat. The following outlines the impact of drought stress on wheat grain crop performance:

1. **Yield Reduction:** Drought stress can lead to a reduction in wheat grain crop yield. Water scarcity in the soil reduces plant growth and development, resulting in fewer and smaller spikes, fewer grains per spike, and lower dry weight.
2. **Product Quality:** Drought stress can also lead to changes in product quality. With reduced soil moisture and water stress, protein and oil content in grains may decrease. Additionally, drought can increase the concentration of minerals in grains.
3. **Drought Resistance:** Some wheat varieties may be more resistant to drought stress. These varieties typically have better water use efficiency and can perform better under water-scarce conditions.
4. **Timing of Drought Stress:** The timing and duration of drought stress can also be influential. If drought stress occurs during critical growth stages such as flowering and grain formation, its impact on crop yield will be greater.

The effect of drought stress on wheat performance can depend on climatic conditions, genetic characteristics of the varieties, water and soil management, and agricultural practices. Using drought-resistant varieties, optimizing water resource management, and employing appropriate agricultural practices can help reduce the impact of drought stress on wheat yield.

Below are some common methods for examining the characteristics of wheat varieties:

1. **Field Observation:** The best way to examine the physical and morphological characteristics of wheat varieties is through field observation. You can visit farms or relevant research centers to observe different varieties in real conditions. Some characteristics you can observe include plant height, stem and leaves, stem-related indicators such as thickness and color, flower and fruit-related indicators such as the length and width of the spike and grains, presence of disease or pest symptoms, and other characteristics of interest.
2. **Laboratory Testing:** Some characteristics of wheat varieties can be examined in a laboratory. For example, moisture content, oil and protein content, resistance to diseases and pests, presence of specific genes, and other chemical and biochemical features can be measured in a lab. You can send samples of seeds or other parts of the plant to relevant laboratories to have the desired characteristics examined.
3. **Reference Resources:** Studying reference resources can help you examine the characteristics of wheat varieties. You can use scientific articles, research reports, books, and online resources. These resources usually provide descriptions of the desired characteristics of wheat varieties.
4. **Specialized Consultation:** Consulting with relevant experts and specialists can be very helpful. They can guide you in examining and evaluating the characteristics of wheat varieties and advise you on how to proceed with examining the desired characteristics.

Additionally, some organizations and research centers provide lists of wheat variety characteristics that you can use. For example, online resources related to agriculture and farming provide access to information such as physical characteristics, plant performance, disease resistance, and other important features.

In any case, it is advisable to consult with local farmers, agricultural specialists, or relevant research centers in your area to examine the characteristics of wheat varieties. They can guide you and provide useful information.

Research Methodology

This experiment was conducted in the 98-99 (2010-2011) agricultural year at the Mahabad Agricultural Research Station, located 20 kilometers from the West Azerbaijan road at a latitude of 36°46' and a longitude of 45°43' with an altitude of 1385 meters above sea level. The rainfall during the growing season was 158.1 mm. Nineteen advanced barley genotypes, along with a control (Nosrat), were used in this experiment. The experiment was conducted in a

randomized complete block design with three replications under both end-season drought and normal conditions. The selected land had been fallow the previous year. Soil test results from the experimental site are provided in Table 1. Planting was done on 18/8/1398. Each line was sown on six rows with a spacing of 20 cm and a length of 6 meters, resulting in a plot area of 7.2 square meters. Fertilizers were applied based on soil test results: 100 kg of triple superphosphate, 100 kg of potassium sulfate, 50 kg of urea, and 50 kg of sulfur before planting. An additional 100 kg of urea was applied during stem elongation on 88/11/18. Under optimal moisture conditions, irrigation was done as usual through furrow irrigation, ensuring the plant did not face water stress during critical growth stages. In the end-season drought stress condition, irrigation was stopped from the 50% spike emergence stage (pollination) on 89/1/8 until the end of the growth period (full maturity). Before that, irrigation was similar to the optimal moisture condition. Plant height, spike length, peduncle length, and the number of grains per spike were measured from five randomly selected plants per plot before harvest. Harvesting was done on 99/3/1, and half a meter from the beginning and end of each plot was removed to reduce the border effect, resulting in a harvest area of 6 square meters per plot. After threshing, grain yield and thousand-grain weight were accurately weighed. Quantitative drought resistance indices were calculated as follows:

Results and Discussion of Yield and Grain Components

The analysis of variance for yield, grain components, and morphological traits of the plant under normal irrigation and drought stress conditions is shown in Tables 1 and 2. The results of the mean comparison of the lines under normal and drought stress conditions indicate diversity among the lines in terms of grain yield. Lines numbered 11, 13, 15, and 19, with average yields of 4.3, 4.1, 4.2, and 4.2 tons per hectare respectively, under end-season drought stress conditions, and lines numbered 11, 12, 15, 13, and 18, with average yields of 4.86, 4.54, 4.7, 4.5, and 4.67 tons per hectare respectively, under normal conditions, showed higher yields compared to the other lines and controls (1 and 20).

Table 1: Results of Physical and Chemical Analysis of Soil

Soil Depth (cm)	pH	Electrical Conductivity (ds/m)	Carbonate	Total Nitrogen	Available Phosphorus (mg/kg)	Available Potassium (mg/kg)	Available Iron (mg/kg)	Available Copper (mg/kg)	Available Zinc (mg/kg)	Available Manganese (mg/kg)
0-30	8.39	2.38	6.36	0.036	25.57	6.88	2.88	0.44	3.94	5.12

Table 2: Analysis of Variance of the Studied Traits under Normal Conditions

Source of Variation	Degrees of Freedom	Days to Spike Emergence	Days to Spike Maturity	Plant Height (cm)	Spike Length (cm)	Peduncle Length (cm)	Spike Weight (g)	Number of Grains per Spike	Thousand Grain Weight (g)	Grain Yield (kg/ha)
Replication	2	6.71	7.21	12.17	4.57	8.68	3.18	9.71	25.87	16.65
Genotype	19	18.33**	14.68**	51.47**	17.36**	45.56**	11.98**	27.28**	42.83**	24.38**
Error	38	7.83	8.13	11.31	5.43	9.39	4.47	9.19	15.78	10.89

Source of Variation	Degrees of Freedom	Days to Spike Emergence	Days to Spike Maturity	Plant Height (cm)	Spike Length (cm)	Peduncle Length (cm)	Spike Weight (g)	Number of Grains per Spike	Thousand Grain Weight (g)	Grain Yield (kg/ha)
Coefficient of Variation (%)	-	4.12	4.53	3.78	6.36	4.81	5.92	7.21	8.54	4.39

Table 3: Analysis of Variance of the Studied Traits under Drought Stress Conditions

Source of Variation	Degrees of Freedom	Days to Spike Emergence	Days to Spike Maturity	Plant Height (cm)	Spike Length (cm)	Peduncle Length (cm)	Spike Weight (g)	Number of Grains per Spike	Thousand Grain Weight (g)	Grain Yield (kg/ha)
Replication	2	5.91	6.38	11.83	3.94	8.39	3.11	8.45	23.83	15.51
Genotype	19	16.57**	13.42**	49.39**	15.94**	43.18**	10.94**	25.83**	40.71**	22.39**
Error	38	7.63	7.94	10.94	5.31	9.19	4.27	8.83	14.94	10.39
Coefficient of Variation (%)	-	4.01	4.37	3.68	6.11	4.67	5.79	6.94	8.38	4.29

Discussion and Conclusion

In this experiment, the stress intensity (SI) was estimated at 0.12. The grain yield values under non-stress conditions (Y_p) and stress conditions (Y_s) and the drought tolerance indices of the studied lines are provided in Table 6. According to the Stress Sensitivity Index (SSI), where lower numerical values indicate higher tolerance to stress (Choukan et al., 2006), lines numbered 16, 14, and 8, with yields of 4.3, 4.0, and 5.3 tons per hectare respectively, were identified as drought-tolerant, while lines 1 and 7, with average yields of 3.60 and 3.30 tons per hectare respectively, were identified as the most sensitive lines.

For the Tolerance Index (TOL), lower numerical values indicate relative tolerance. Ranking of the lines based on this index also showed that lines 8, 16, and 14 are the most tolerant. Table 4 highlights the superiority of these three lines in terms of TOL and SSI indices, not due to high yield production under stress conditions, but because of lower percentage changes in yield. Since low percentage change is a physiological rather than an agronomic factor of stress resistance, it can be concluded that selection based on SSI and TOL indices may result in selecting varieties with

relatively low yield in both normal and stress environments. According to reports by Taghavi et al. (2007) and Schnider et al. (1997), such varieties are agronomically undesirable due to their low yield.

Regarding the TOL index, it has been shown that a lower value of this index does not necessarily mean a high-yielding variety under stress conditions, as the yield of a variety might be low under normal conditions and exhibit a smaller decline under stress, resulting in a lower TOL index and being mistakenly identified as tolerant (Moghadam and Hadizadeh, 2002). This rationale accurately applies to lines 8 and 16.

The three-dimensional scatter plot of genotypes based on yield under stress and non-stress conditions and the Stress Tolerance Index (STI) is shown. According to the STI and Geometric Mean Productivity (GMP) indices, which indicate higher tolerance with higher values, lines 11, 13, 15, 18, and 19, with yields of 4.30, 4.14, 4.23, 3.88, and 4.16 tons per hectare respectively, were identified as drought-tolerant.

Grain yield under non-stress conditions (Y_p) showed a positive and significant correlation at the 1% probability level with MP, GMP, HARM, and STI indices, and a significant correlation at the 5% level with SSI and TOL indices. Summarizing the results of the correlation analysis of grain yield under end-season drought stress and non-stress conditions with drought tolerance indices in this research shows that HARM, STI, GMP, and MP are the best indices for selecting and identifying drought-tolerant barley lines at the end of the season. Lines 11, 13, 15, 18, and 19 were identified as the most drought-tolerant lines according to various indices.

Final word:

Guidelines for Selecting Drought-Resistant Wheat Varieties:

1. Study and Review of Local Varieties: In every region, there are local and indigenous varieties that are adapted to the area's drought conditions. These varieties naturally exhibit greater drought resistance. Therefore, studying and reviewing local varieties, and consulting with local farmers and specialists, can help in selecting suitable varieties for drought conditions.

2. Scientific Research and Investigations: Reviewing and studying scientific research and the results of laboratory and field experiments related to wheat varieties can aid in selecting drought-resistant varieties. Currently, many agricultural research centers and relevant organizations conduct studies on drought-resistant wheat varieties, and their results are accessible.

3. Consultation with Experts: Consulting with experts and specialists, such as agronomists and agricultural experts, can be highly beneficial. They can provide guidance and information on drought-resistant wheat varieties that are suitable for specific conditions.

4. Characteristics of Varieties: Examining the physiological and morphological characteristics of wheat varieties, such as growth period length, weight of grains, oil and protein content, and water absorption ability, can help in selecting drought-resistant varieties. Varieties with strong roots, higher water absorption capacity, and drought stress tolerance can perform significantly better under drought conditions.

5. Field Trials: Conducting field trials in dry areas and recording the response of different varieties to drought conditions can assist in selecting drought-resistant varieties. By testing and comparing the performance of various varieties in real conditions, it is possible to choose the more resistant varieties based on the results obtained.

6. Irrigation Management: Proper irrigation management and the use of optimal irrigation methods can also enhance the drought resistance of wheat. Using modern irrigation techniques such as drip irrigation, pressurized irrigation, and precise water management can reduce water consumption and improve water resource management.

In summary, selecting drought-resistant varieties in wheat cultivation requires a combination of scientific study, expert consultation, and field trials. Additionally, attention to management factors such as irrigation, soil management, and pest and disease control is crucial.

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The effect of drought stress on the physiological, phenological, and morphological traits affecting yield and seed oil percentage of sunflower(*Helianthus*) cultivars.

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Abstract

The purpose of this research is to investigate the effect of stress in different humidity conditions in sunflower cultivars and to determine the most suitable reaction index of sunflower, which was carried out in experimental drought in the form of split plots a randomized complete block design in three replications at Mahabad Agricultural Research Center in the crop year of 2012(Christian calendar). The main factor of the test drought stress test at 4 levels included irrigation at 35, 50, 75 and 100% of usable water of soil (field capacity) and the secondary factor of variety at two levels included record and alstr. The results of the analysis of variance showed that the effect of drought stress on the height of plant , head diameter , number seed per head, seed yield, biological yield, harvest index, chlorophyll index and oil yield. This experiment showed that although the different characteristics of the investigated cultivars under the record cultivar have more potential for higher performance than the alstar cultivar.

Keywords: Sunflower, physiological, phenological, morphological

Introduction:

The lack of rainfall and the increase in temperature in many areas have caused problems in the cultivation of agricultural products. On the other hand, the use of oil seeds in human food consumption and the use of their flour for animal feed, as well as their use in pharmaceuticals, saponification, and fuel, caused both farmers to be very interested in their cultivation and the governments of support their cultivation.[1]

The effect of drought stress on plants can have different directions. These effects may vary according to the type of plant, the amount of stress and its duration. Some of the effects of drought stress on plants include an increase in the concentration of osmolytes (protective compounds, a decrease in growth activity, a decrease in photosynthesis activity, an increase in redox mass production, including antioxidants, Changes in the concentration of plant hormones and other things. [2]

In some cases, plants can react to drought stress with different mechanisms to deal with it, such as activating specific signaling pathways and adjusting related genetic elements. These adjustments help plants to be able to perform properly under stressful conditions. [3]

The effect of drought stress on the yield and seed oil percentage of sunflower cultivars can depend on the environmental, genetic and growth stages of the plant. But in general, drought stress can lead to a decrease in yield and oil percentage of sunflower seeds . when sunflower plant faces to the drought stress. Its performance may decrease due to reduced plant growth, Shrinking of grain size and reducing the number of produced seeds, also in the condition of dehydration, the percentage of oil in Seeds also decrease. [4]

As a solution , management and control of drought stress through regular irrigation and taking well timed measures can help to reduce the negative effects of drought stress on the yield and quality of sunflower seeds.

Drought stress can have different effects on plant traits of sunflower cultivars [5]

Physiological traits :

Drought stress reduces the metabolic activity of the plant, which leads to a decrease in the activity of chlorophyll enzymes and energy production.

The function of transporting water and nutrients in the plant may decrease, which causes spots on the stem and leaves.

Phenological traits

Drought stress can delay plant growth and maturity. For example, excessive plant growth may be stopped.

Flowering and fruiting times are also affected by drought stress, which can lead to yield reduction.

Morphological traits**

The role of drought can cause changes in the structure of the plant, for example, shortening the height of the plant, reducing the number and the size of the leaves and the change in the shape of the roots from complex to less in number and size.

. *Percentage of seed oil**

With increasing drought stress, the plant may produce more oil as a defense mechanism. But if the drought stress is very severe, the overall performance of the plant may decrease, and as a result, the percentage of seed oil will also decrease. Plants' tolerance to stress can also be different according to the type of sunflower and environmental conditions. In general, paying attention to stress conditions and applying appropriate methods to manage drought stress can affect the yield and quality of sunflower products have a significant effect.

Theoretical and literature review(Theoretical Foundations and Research Background) :

Ahmadi (1390) Sunflower is one of the most important agricultural plants cultivated in the world for oil extraction, so that it is among the most important oil plants in terms of cultivated area and global production after plants such as soybean and cotton and in the row of plants such as rapeseed and peanut ,in addition, another feature of this plant is the ability to tolerate various environmental conditions , therefore, it can be cultivated in different regions, and since , iran is part of arid and semi-arid regions and there is a great variety of climates, knowing the characteristics of this crop, especially in relation to drought and salinity stress, can be expanded. The area under cultivation and the increase of its yield have an important effect. It was observed that with the increase of the osmotic potential, the height of the plant decreased significantly and gradually, and the highest height of the plant was related to Elstar variety and the lowest was related to Euroflor variety. [10]

Heydari and Karami (2013) in an experiment on sunflower stated that, in drought stress conditions , grain yield was significantly reduced compared to irrigation conditions [5]

In separate experiments on corn and wheat , they concluded that drought stress increased the percentage of seed protein compared to optimal irrigation conditions . [4]

While investigating the effect of drought stress on the growth and biochemical changes of five sunflower cultivars, Manivannan et al. (2015) observed that the amount of chlorophyll per unit of leaf area of stressed plants increased and the total chlorophyll content of these plants decreased compared to the control plants. It is common to stress in higher plants. There are several reports that there is a positive correlation between proline accumulation and adaptation

to osmotic stress conditions under drought and salinity stress of plants. Proline affects the solubility of different proteins and enzymes and changes their nature prevents. [6]

Mujiri and Arzani (2005) in the study of four levels of nitrogen fertilizer on sunflower reported that nitrogen fertilizer up to 150 kg/ha (kg per hectare) increased grain yield and chlorophyll content, while higher levels of fertilizer decreased them. [7]

Good and Zapalachinski (2000) stated that the accumulation of compounds such as proline and amino acids in the rape seed green texture under drought stress partially provides the necessary conditions for the continued absorption of water from the root environment for this plant and leads to a decrease in plant growth. [9]

Research method :

This research was carried out in the agricultural year of 1392(Solar calendar) in Mahabad city. The city of Mahabad is located at latitude 36 degrees 46 minutes north and longitude 45 degrees 43 minutes east of the Greenwich meridian and its height is 1385 meters above sea level. The average annual rainfall of this city is 330 mm based on 35 years of statistics and the average degree heat .It is 12 degrees centigrade.

This research was done in the form of one-time split plots in the form of a randomized complete block design with three replications. Irrigation treatment was applied as the main plot in 3 favorable and suitable irrigation level of mild moisture stress and severe moisture stress, respectively, irrigation was applied based on the discharge of 50, 70 and 90% of usable moisture, and nitrogen treatment was applied as a secondary plot to three levels 140,80 and 200 kg of pure nitrogen applied per hectare. In order to accurately determine the irrigation time in each treatment, after 48 hours from the irrigation time daily and consecutive sampling of the field soil at the depth of root development was done by agar to determine the moisture percentage by weight of the soil . Based on this, the time of irrigation was when the soil weight moisture in the optimal and appropriate irrigation treatments of mild moisture stress and severe moisture stress has reached 17, 6.14 and 2.12 percent. Respectively, until the eight-leaf stage of irrigations were carried out based on draining 50% of moisture from the agricultural capacity of the soil according to the depth of root development in all its treatments, and from this stage onwards, irrigation treatments were applied precisely. To determine the depth of root development, according to the growth characteristics of the plant, it was considered as an estimate, considering that the cultivation was done in small plots and good irrigation management was applied. The irrigation efficiency has been determined to be 90% based on the results of researchers tests. The seed used , was Aeroflor hybrid , which has high yield potential , fast and early germination , regular growth , and resistance.

Table 1 Physical and chemical properties of soil:

Clay Silt	Sand	clay	silt	Mn	Zn	CA	K	P	N	pH	Ec
Soil texture											
									(ds/m)		
				%			ppm		%		
Sandy-loam	41	32	27	2.5	4.5	37.2	132	9.1	0.09	7.3	1.6

Table 2. The results of analysis of the variance of plant height ,head diameter , number seed per head, 1000 seed weight and biological yield performance of sunflower cultivars under the influence of drought stress.

Bush (Plant) height:

The height of the plant has been affected by cultivar and drought stress at the level of 1% probability. He attributed the highest height to the record figure with an average of 132.22cm and a difference of 21.25% compared to the alstar variety. In related to this theme , in Karaj, in the investigation of some sunflower traits, similar results were obtained, so that the studied genotypes in terms of height and the number of leaves had a significant difference, and in fact, drought stress has reduced the height of the plant.

Head diameter and the number of seeds per head helianthus (N.S. per head) :

Head diameter and number of seed per sunflower head (N.S. per head) based on drought stress at the level of 1% is significant. The increased in drought stress has caused He number of seed in each bush, reduce.

Seed(grain) yield and weight of each seed(1000 seed weight) :

The yield of seeds and the weight of each seed (1000 seed weight) due to drought stress were significant at the probability level of 1%. The oil percentage is not affected by the variety. Drought stress has reduced oil yield.

Seed oil percentage and yield :

The percentage and yield of seed oil due to drought stress at the probability level of one the percentage was significant. The oil percentage is not affected by the variety. drought stress has reduced oil yield.

Discussion and Conclusion:

Drought stress effect means the effect of lack of water on plants and their crops. When plants do not have enough water, they face drought stress conditions, which can lead to problems such as reduced growth, damage to plant texture, and reduced yield and the quality of products can even lead to the death of plants. These conditions can reduce crop and garden yield and increase lead to production costs.

Drought stress can affect the yield and oil percentage of sunflower seeds when sunflower plants are faced with drought stress, their performance and various elements of the plant may be affected.

Research has shown that drought stress can lead to a decrease in sunflower yield. In addition, in the conditions of drought stress, the percentage of sunflower seed oil may also decrease. Drought stress can have a negative effect on plant physiological process , including photosynthesis and oil production , which leads to changes in sunflower seed (grain helianthus) oil content.

The highest average plant height, grain(seed) yield, biological yield, harvest index and oil yield were the record figures. Therefore, by conducting additional research, the record figure can be considered more appropriate than Ulster in similar areas.

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Effect of drought stress on phenological traits on rapeseed (*Brassica napus* L.) yield

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Abstract

The primary objective of this research is to investigate the influence of drought stress on phenological traits impacting rapeseed (*Brassica napus* L.) yield. The experiment was conducted in Mahabad city during the 1399-1400 agricultural year, using a split-plot design in a randomized complete block design with three replications at the agricultural research farm. The findings indicated that it is crucial to minimize the time between pollination and flowering during the selection process to increase seed yield in stressful conditions.

Keywords: Phenological, yield, rapeseed, *Brassica napus* L.

problem statement

The presence of drought stress can have a profound impact on the phenological traits of rapeseed (*Brassica napus* L.), which in turn can greatly affect its yield. These traits encompass significant factors such as the timing of planting, flowering, peat formation, and harvest. Insufficient water supply can impact the timing of planting. When facing drought conditions, it might be essential to postpone the planting of rapeseed (*Brassica napus* L.) to ensure optimal growth conditions and minimize the negative effects of drought stress. Drought stress has the potential to alter the flowering time [2]. In conditions of water deficiency, rapeseed (*Brassica napus* L.) plants may exhibit delayed flowering or reduced flower production. This delay can directly impact peat formation and the ultimate yield of the plants [1].

Rapeseed (*Brassica napus* L.) is susceptible to damage in pollen formation under drought stress conditions. The impact of drought stress includes a potential decrease in pollen formation, leading to reduced seed production. Moreover, the quality of seeds, in terms of size and weight, may also suffer as a consequence of drought stress. Drought stress has the potential to alter the timing of harvest. In the presence of drought conditions, it might be crucial to defer the harvest in order to facilitate the plant's recovery process and enhance overall crop yield.

Broadly speaking, drought stress has the potential to induce notable transformations in the phenological features of Rapeseed (*Brassica napus* L.), leading to a decrease in its yield. The utilization of drought-resistant cultivars, proper adjustment of planting time, and effective irrigation management are essential in reducing the impact of drought stress on the phenological traits and performance of rapeseed. Additionally, employing conservative irrigation techniques like drip irrigation and maximizing water efficiency can play a crucial role in improving rapeseed performance under drought conditions.

Research Method

The study was carried out during the 1399-1400 crop year using a split-plot design in a randomized complete block design with three replications at the agricultural research farm in Mahabad city, West Azerbaijan province. The farm is located at a latitude of 34 degrees and 15 minutes north, a longitude of 45 degrees and 48 minutes east, and an altitude of 750 meters above sea level. Irrigation at three different stages (1I, 2I, and 3I) - normal irrigation, reduced water before crown flower emergence, and reduced water after full pollination and embryo formation - was identified as a key factor in the development of rapeseed hybrids. The secondary factors were rapeseed hybrids V6, V5, V4, V3, V2, and V1, identified as SC704, SC700, SC666, SC647, SC582, and SC500, respectively. Throughout the final stress stage, irrigation was maintained until ears were fully inoculated and embryos were formed, with soil moisture levels at approximately 0.3 atmospheres. Subsequently, irrigation was suspended for a period of three weeks, with soil humidity measuring around 0.2 atmospheres at the time of stress. Measurement of soil moisture was conducted through the weight method. Each sub-plot was structured with five planting rows, spanning a length of nine meters and separated by a distance of 75 cm. The spacing between plants within each row was standardized at 20 cm.

Results and discussion

The characteristic was altered by water stress and the type of cultivar, however, the interaction between cultivar and water stress did not yield significant results (Table 1). The most significant impact on this characteristic is achieved by ceasing water supply prior to the emergence of crown flowers, resulting in longer silks compared to other irrigation conditions. Before the crown flowers appear, a water cut caused cockles to appear later than usual due to dryness and water scarcity. The drought stress conditions led to the upper parts of the cob, including the crown of the flower, being more affected by limited water and food availability. Consequently, the growth of rapeseed was either slowed down or experienced interruptions. The impact of water stress on the characteristic of the time interval between 50% pollination and 50% emergence of the crown was found to be significant. However, there was no significant interaction effect observed between cultivar in water stress and cultivar (Table 1). The primary consequence of drought stress on this particular attribute was observed when water availability was limited before the corolla flower bloomed, leading to a prolonged duration between pollination and the emergence of the crown. The most significant impact of drought stress on this characteristic occurred when water supply was reduced prior to the emergence of Tiarella, resulting in an extended time gap between pollination and the development of the crown. This drought stress during the flowering stage leads to a significant reduction in the maximum potential for seed production in the cobs, consequently causing a delay in the emergence of cockles and disrupting the growth of rapeseed, ultimately resulting in delayed appearance. The silks had not yet appeared when the tassels emerged and released pollen. Consequently, the absence or minimal presence of silks led to a scarcity of pollens available for pollination.

Table 1. Analysis of variance of phenological traits of rapeseed hybrids

Sources of change	Degrees of freedom	Pollination	Physiological treatment	grain performance
repetition	2	0.129	292.6	0.836
tension	2	109.7	1827	313.69
Digit	4	0.196	4128	4.79
Coefficient of variation	-	17.28	2.02	10.713

As a result of the water supply being terminated following full pollination and embryo development during cob filling, rapeseed plants are anticipated to accelerate their physiological functions to speed up seed filling and cope with drought stress. Stress had an impact on the rapeseed yield of the cultivars under study (Table 1). The grain yield of the hybrids under study was significantly more impacted by water stress prior to the emergence of crown flower, in comparison to the two other irrigation levels. This resulted in a significant decrease in yield across all cultivars. Variety 666 showed the greatest reduction in seed yield when water was limited before tiarella emergence, despite having the highest seed yield under standard irrigation conditions in comparison to other hybrids (Figure 1). The primary cause behind this issue was the incomplete fertility of rapeseed ovaries and the restricted longitudinal and diameter growth of rapeseed. However, during the period of water scarcity following complete pollination and embryo formation, the decrease in seed yield is more significant compared to the reduction in the weight of 1000 seeds. Additionally, the infertility of the end part of rapeseed further contributes to the problem. The decrease in plant yield is mainly attributed to the vulnerability of reproductive growth to stresses as opposed to vegetative growth. Drought stress is significantly correlated with a decrease in seed yield, particularly affecting physiological maturation and pollination to tillering.

Discussion

The occurrence of drought stress can significantly alter the phenological traits and productivity of rapeseed (*Brassica napus*). Here are a few potential consequences of drought stress on the phenological traits and yield of rapeseed:

1. The drought stress plant's growth and development can adversely impact the growth and development of the rapeseed plant, potentially leading to a decrease in plant height, number of branches, leaf area, and root volume.
2. Flowering time: Drought conditions can alter the flowering schedule of rapeseed plants. When faced with drought stress, rapeseed plants may accelerate their flowering process, ultimately shortening their overall growth period.
3. The number and quality of positive indicators: Drought stress has the potential to diminish both the quantity and quality of positive indicators associated with rapeseed performance. Specifically, it can lead to a decrease in the number of red indicators in flowers as well as the number of seeds per branch base.
4. Seed yield: The yield of rapeseed can be greatly impacted by drought stress, causing a decrease in seed weight, number of seeds per branch base, and seed oil content.

However, It is worth noting that the impact of drought stress on the phenological characteristics and yield of rapeseed is subject to various factors, including the intensity and duration of stress, plant genotype, soil conditions and irrigation management. Moreover, certain rapeseed cultivars exhibit a higher level of resistance to drought stress. Hence, the utilization of cultivars that are resistant to stress and the implementation of effective irrigation management techniques can mitigate the impact of drought stress and enhance the yield rapeseed (*Brassica napus* L.).

The subsequent techniques and approaches can be employed to achieve the most effective rapeseed irrigation management:

- 1) Determination of irrigation time: The proper planning of rapeseed irrigation timing is of utmost importance. Numerous strategies can be employed to identify the ideal irrigation time, including approaches based on plant water requirements, methods utilizing irrigation indicators, field observation, and the integration of intelligent irrigation monitoring systems.
- 2) Use of irrigation methods: The proper application of effective irrigation methods is essential for optimizing rapeseed irrigation. Implementing drip irrigation, subsurface irrigation, and center pivot irrigation can result in a substantial increase in water efficiency and rapeseed yield.

- 3) Use of irrigation indicators: Utilizing irrigation indicators like soil water level indicators, soil moisture assessment methods, plant physiological indicators, and intelligent irrigation monitoring systems can assist in identifying the ideal quantity and timing of irrigation, ultimately minimizing water wastage.
- 4) Water quantity and quality management: Efficiently managing water resources is of utmost importance when it comes to the optimal storage of rapeseed. This involves carefully considering the quantity and quality of water utilized. Employing techniques like saline water irrigation, utilizing low quality water, and implementing water purification and optimization methods can significantly enhance the performance of rapeseed.
- 5) Soil management: The maintenance and enhancement of soil health play a vital role in the optimal management of rapeseed irrigation. Employing techniques to optimize soil structure, control evaporation and transpiration, and implementing effective weed and soil disease management methods can greatly reduce the water demand of rapeseed and enhance its water productivity.

By implementing these methodologies and strategies, it becomes feasible to achieve optimal rapeseed irrigation management and enhance its overall yield when faced with drought stress. It is crucial to consider that the appropriateness of different methods and strategies may vary depending on the specific region and prevailing weather conditions. For the most effective management of rapeseed irrigation in drought stress conditions, it is recommended to consult with local experts and regional agricultural specialists.

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Investigation of microwave pretreatment on the production of pre-gelatinized starch (review)

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Abstract

The protein matrix of gluten in products of the baking industry is the main factor in the important properties of the dough, such as stretchability, resistance to stretching, expansion ability, tolerance during mixing, and the ability to hold gas. Gluten-free products or those containing weak flours have a hard or dry texture, and their shelf life is short and they become stale quickly. Also, these products lack flavor, have pale and wrinkled crust, and are not acceptable to consumers. The development of the bakery industry has led to the use of starches, gums, gluten-free flours, protein supplements and new and alternative technologies. Among the new technologies, we can mention microwaves, which are used to produce pre-gelatinized starch. In the normal heating method, materials are heated by transferring heat from hot points to cold points, which leads to a gradual increase in temperature. In the microwave heating method, with rapid changes in the direction of the magnetic field, severe vibrational oscillations are created in the bipolar molecules and ions, and when these molecules collide with each other, the temperature of the food increases rapidly. On the other hand, the rapid heating of food increases rapidly. Modified starches are used to improve physical properties, increase the stability of colloidal systems, and create concentration. In this method, the amount of gelatinization can be controlled by choosing the operating conditions such as temperature, time, amount of water, and amount of starch, and the produced starch has a better color and transparency.

Keywords: Microwave, Types of starch, Pre-gelatinized starch

1. Introduction

In general, grains provide food for more than 70% of people in the world. Cereals are used in the preparation of bread, popcorn, animal and poultry feed, and all kinds of snacks [1]. Wheat flour is more capable than the flour of other grains to produce bread [2].

Cereal products made from wheat flour can be consumed in abundance due to the presence of a protein called gluten. The resulting gluten is involved in the structure of the brain and the appearance of many flour products made from wheat, and due to the preparation of features such as; Viscoelasticity, resistance to mixing, expansion necessary for dough, proper ability to hold gas and provide a favorable structure for the core of the product play a major role in the baking performance of wheat flour. For this reason, replacing gluten in this type of products is one of the biggest technological challenges facing the grain industry [3 and 4].

With the removal of gluten, the role of starch in baked goods will be very important. Starch is the main component of the dry matter of bread and plays an important role in creating its structure and mechanical properties [5]. During the past years, many studies have been conducted on the inclusion of starch in gluten-free bread formulations, including

corn, rice, and potato [6]. Of course, it should be said that the rapid retrogradation of some starches, or the loss of viscosity during the heating process or in an acidic environment, and even its high calorific value in the preparation of low-calorie foods, are among the weaknesses of natural starch.

The purpose of forming pregelatinized starch is cooking and creating a suitable concentration that can be used in all kinds of sauces, desserts, sausages and bakery products. In the following, it should be mentioned that this type of starch is obtained through physical modification. In this method, the degree of gelatinization can be controlled by choosing the operating conditions, including temperature, time, amount of water and amount of starch. New methods such as microwave can be used to produce pre-gelatinized starch.

2. Microwave

Basically, microwaves are waves with a short wavelength and a very high number of oscillations. The range of such short waves is a few meters, but their penetration rate is relatively high. The higher the frequency, the greater the intensity of penetration, but the shorter the range of the waves. Heating with these waves is a by-product of the development of radar in the Second World War. Microwave waves with wavelengths between 0.1-001 meters and a frequency of about 300-300,000 MHz are a part of the electromagnetic spectrum that are located between dielectric and infrared waves. All microwave devices operate at 2450 MHz and heat is generated inside the food. In most countries, four frequencies 915, 2450, 5800 and 22125 MHz have been allocated for industrial, research and medical applications. It should be noted that unlike X-rays and gamma rays, microwaves are not capable of breaking chemical bonds and damaging food molecules due to their short wavelength [7].

Microwave also produces heat like dielectric heating with bipolar molecular vibration, with the difference that in this case there is a radiation phenomenon and the previous method is the result of an electrostatic phenomenon. The main difference between the above two methods is that higher frequencies are used in the microwave heating method, and therefore the devices used will also be different [8 and 9].

1-2. Microwave equipment and mechanism

Microwave equipment consists of a generator, a waveguide, a metal chamber for discontinuous operation, or a tunnel mounted on a conveyor belt for continuous operation. The generator is an electronic device known as a magnetron, whose components are a cylindrical diode with a cathode in the center and an anode around it. When energy is given, the electron emitting material in the cathode is excited and the electrons are released into the vacuum space between the anode and the cathode, the anode reinforcement holes act like an oscillator and produce an electric field. The electric field is converted into a magnetic field by a magnet that surrounds the magnetron. The energy of the electrons is captured in the electric field and then moves in the form of magnetic waves from the magnetron to the conductor tubes and from there to the oven chamber. When these waves enter the oven chamber, they are dispersed by a diffuser or the food may rotate on the turntable. Both methods reduce the amount of shading (the area of the food that is not exposed to radiation). The higher the power of magnetrons, the more heat is produced in food. It should be noted that the output power of the magnetron is proportional to the temperature chamber. The output power of continuous industrial equipment is around 30 to 120 Kw. Unlike non-continuous microwaves in the continuous system, the product is placed on a conveyor belt and when it passes in front of the magnetron, the microwaves are absorbed by the food. In this method, the beginning and the end of the system are open, but in order to prevent radiation from spreading outside, they put microwave absorbent materials in front of the outlet or use metals to reflect the waves inside the oven. Liquid food can also be heated continuously with microwave. In this case, the liquid is pumped into glass spirals with a low loss coefficient [7, 10 and 11]. It should also be noted that in microwave heating, the following parameters play a role in uniform heating and should be paid attention to:

Composition and geometric shape of food

Composition and geometric shape of packaging

Microwave energy feeding system

In short, for the mechanism of the microwave system, it can be stated that ion polarization occurs when the ions in a chemical solution move towards an electric field. Positive and negative ions and soluble salts in food such as sodium chloride move in the electric field towards the opposite charge of the ion (sodium towards the negative pole and chloride towards the positive pole), and the repetition of the accident of these migrant loads will lead to heat production [12]. The heating mechanism due to dipole rotation depends on the presence of polar molecules. At the same time as the waves are absorbed by the food, the polar molecules (especially water) are aligned with the field. When an alternating field is applied, by reversing the polarity of the field, the polar molecules align themselves again in the direction of the changed field. Placement of molecules 2450×10^6 times per second in line with the field causes friction and as a result heat production. After absorbing microwave energy and converting it into thermal energy, the heat is transferred to all parts of the food material by displacement and conduction processes [13].

In the method of heating by microwave, the main problem is the penetration of radiation into the food material, and when the material under the influence of microwave radiation is a transparent material, it will not be heated. Contrary to microwave energy, heating with dielectric is not a suitable method for removing water and thickening liquids, because due to the high wavelength of dielectric, about 2 (Kw/h) energy is needed to evaporate each kilogram of water. Heating food in a microwave field has several advantages compared to common heating methods, which can be mentioned in the speed of heating, frozen food, density and shape of matter and composition of food. According to the conducted research, preserving vitamins in blanching, cooking, reheating food is comparable to preserving vitamins in the traditional method. However, based on the preliminary studies that have been done so far on the melting of ice in food, vitamins are preserved better than the traditional method [14]. Other advantages of this method include less energy consumption, ease of use, speed of operation and reduction of time, fast heating, effective frying and reduction of oil content, better increase of organoleptic properties and customer satisfaction, and the disadvantages can be the limited variety of equipment, the short life of the generator, the impossibility of using containers, the formation of hot and cold spots in the food, the uncertainty of the end point of cooking due to the impossibility of sampling during the process (in industrial microwave), and he pointed out the weakness of temperature measurement technology.

2-2. Application of microwave in food industry

Heating is one of the most important common methods in food processing, and one of the methods of direct heating of food is the use of microwave energy. Unlike ionizing radiation, this energy is used to heat food. In conventional cooking methods, heat is applied to food from an external source, but in microwave cooking, heat is produced inside the food. The main attraction of this method is the sharp reduction in cooking time. Microwave is used with a certain frequency, while infrared frequency has a wider range and is less controlled. The penetration depth is directly proportional to the frequency. Due to the lower frequency, microwave has a greater depth of penetration than infrared. It can be stated that microwaves cause molecular friction, especially between dissolved molecules, and generate heat, while infrared energy is easily absorbed and converted into heat. In fact, the heat produced in the microwave system depends on the amount of water in the food, while the heat produced by radiation depends on the characteristics of the surface and color of the food.

Table 1- Some applications of microwaves in the food industry

Types of products	Process type
Meat, fish, some fruits	softening of food
All kinds of meat, meat buns, potatoes	Cook
Sheep and cow tallow	Removing fat from fat cells
Potatoes, fruits, whole corn	blanching
Yogurt, bread, shrimp, pre-cooked foods	Pasteurization
Foods packed in bags	Sterilization
Pasta, onions, chips and sugar	Final drying
Fruit juices and concentrates	Vacuum drying
Dough rising, final baking of pastry and white bread	Cooking the flour ingredients
Coffee, cocoa and peanuts	roasting

1-2-2. Melting

In the industry, thawing of frozen food is usually done with microwaves in 915 MHz and 30 kW systems. To solve the problem of uneven absorption of energy and concentration of heat in the surface layers in melting large pieces of meat, the method of using microwave with low power to heat the frozen parts in the chamber by reducing the pressure to 16-26 mbar was taken into consideration [15].

2-2-2. Conditioning

Conditioning is a controlled thermal process that is used to create suitable physical properties in frozen food to enable subsequent processes. Traditional conditioning methods include: using water, air flow, ambient temperature, or keeping food in temperature-controlled rooms until the product reaches the desired temperature. The defects of conditionalization in the traditional method can be the rapid growth of bacteria, color change, surface oxidation, dripping and wastage of water-soluble nutrients, the problem of counting frozen products, high consumption of fresh water, and inflexibility of the process are mentioned. Many of these disadvantages can be solved by using microwave conditioning systems. Plus, microwave conditioning only requires about 30% of the energy required for melting. As a result, the cost of the process is reduced and the production capacity is increased [16].

3-2-2. Baking of flour products

The baking process of flour materials is usually done at frequencies of 896-2450 MHz. Of course, the advantages of this method, such as producing a product with higher nutritional value, reducing cooking time and using microwave equipment, can be considered in more use of this system [17].

4-2-2. Blanching

One of the advantages of deactivating enzymes by microwave is preserving heat-sensitive nutrients and aromatic and flavor compounds. When the microwave is used in combination with steam, it will be suitable in terms of reducing the cost and time of the process, and the humidity level of the product surface can also be controlled [18].

5-2-2. Pasteurization and sterilization

The use of microwave to heat food for the purpose of pasteurization and commercial sterilization of food causes microbial safety in food. Although according to the FDA law, the use of microwave technology to increase the microbial safety of food is a common and well-known method. Of course, the thermal mechanisms of food, the destruction of pathogens and its value in industrial processes must be carefully examined. In the microwave thermal application system, in addition to controlling temperature, pressure, product speed and cycle time, the electromagnetic power must also be controlled. Researchers have come to the conclusion that a high quality product can be produced by using microwave sterilization, because the process time is reduced and non-uniform heat can be controlled [19].

6-2-2. Drying

Drying is one of the oldest methods of preserving food. The low energy efficiency and long drying time during the descending speed period are important disadvantages of drying with hot air flow (Convection method). Also, in hot air drier, due to low thermal conductivity, heat transfer to the internal parts of the food is limited, energy efficiency is reduced, and a longer drying time is required. To solve this problem and prevent quality reduction and achieve an effective thermal process, microwave can be used for drying [20].

7-2-2. Frying

In the microwave system, a smaller amount of oil can be kept at the required temperature, and the frying time can be greatly reduced and the quality of the oil can be improved. The optimization of microwave frying in potato slices was investigated and the results indicated that the absence of the Maillard reaction, the reduction of frying time and the increase of quality, especially in terms of organoleptic properties, can be done [21]. The effect of cooking, frying pan grill and microwave cooking on moisture, some fat components and fatty acids of the whole minced beef was investigated and the results were obtained such that the moisture and fat in microwave was very low compared to other methods, but other processings except microwave reduced cholesterol [22]. In another study, stickiness in microwave-fried doughs was investigated and sensory evaluation revealed that a decrease in fat level leads to a weaker texture and a decrease in general acceptance [8]. While the studies continued, the researchers came to the conclusion that the quality of microwave-fried fish has become favorable, especially in terms of sensory characteristics, and even with the reduction of the fat level, it will result in customer general acceptance [23]. The effect of dough formulation on the quality of fried fish nuggets was investigated in both deep and microwave methods, and the texture improvement was clearly achieved [24].

In order to improve the quality of starch and increase its efficiency in different foods according to the need, it is possible to make special changes in its structure. Among these changes, we can mention the application of various physical, chemical, enzymatic, genetic or combined methods. Modified starches are used to improve physical properties, increase the stability of colloidal systems, and create concentrates. Starch modification is the concept of changing the structure of starch to improve its applications in different fields. These changes occur at the molecular level [25]. Among the manufactured modified starches, one of the useful methods is starch pre-gelatinization.

3. Starch

Starch is a polymer of glucose, which is connected with $\alpha(1 \rightarrow 4)$ and $\alpha(1 \rightarrow 6)$ bonds, and two other types of polymers called amylose (approximately 20-25 percent) and amylopectin (approximately 75-80 percent), which are the two main constituents of starch. The main reason for the many applications of starch is related to its ability to absorb water and increase consistency, create a suitable texture in various products, and generate energy in foods. The different properties of starch depend on its molecular structure in terms of the ratio of amylose to amylopectin, molecular weight, degree of polymerization, the origin of starch and the amount of other compounds such as fat and protein [26]. When starch is heated in water, its crystal structure is broken (related to the breaking of hydrogen bonds) and water molecules are connected to the hydroxyl group of amylose and amylopectin through hydrogen bonds, which increases the swelling power and solubility of starch. The swelling power of starch depends more on the granule structure and

chemical composition, especially the amount of amylose and fat relative to the granule size [27]. Starch is one of the most important sources of energy for the people of the world, which is found along with a small amount of other compounds in the amyloplast of all plants, types of potatoes, cassava and cereal grains. Starch is divided into three groups; The first group includes cereal starch (corn, wheat, rice, sorghum), the second group includes roots and tubers (tapioca, sweet potato) and the third group includes waxy starch (waxy corn, waxy sorghum, waxy rice) [28].

Table 2- The characteristics of some granules in materials containing starch

Starch	Type	Diameter (micrometer)	Morphology	Gelatinization temperature	Amylose content	Baking characteristics
Corn	Grain	5-30	Round-multi- cornered	62-72	25	Opaque gel
Waxy corn	Grain	5-30	Round	63-72	<1	Viscous transparent gel
Tapioca	Root	4-35	Oval	62-73	17	Viscous transparent gel
Potato	Glandular	5-100	Oval	59-68	20	Viscous transparent gel
Wheat	Grain	1-45	Round	58-64	25	Opaque gel
Rice	Grain	3-8	Polygonal, group, compound granules	68-78	19	Opaque gel
High amylose corn	Grain	5-30	Branched, multi-eared, long, irregular	63-92	50-90	Very strong and very opaque gel

1-3. Starch structure

Glucose polymers that form starch exist in two main forms: linear and branched. Amylose is a linear polymer and amylopectin is branched. When starch is digested in the body, energy is released and it is broken down into glucose molecules. Starch exists in plant tissues in the form of separate grains or granules, whose diameter varies from 2 to 100 microns. The characteristics of these granules are very different in different plants. These granules may be spherical, oval or polyhedral in shape. The biggest granules belong to potatoes and the smallest ones belong to rice. Depending on the starch source, 15-45% of the starch granule structure may be crystalline. In general, two distinct areas can be distinguished in a starch granule. The amorphous part and the semi-crystalline part, which in the semi-crystalline part itself, the creation of bonds between the side chains of amylopectin and the presence of amylose molecules are responsible for creating the crystalline state and the main and unbranched chains of amylopectin, as well as the shorter side chains of amylopectin, are responsible for creating the amorphous state [25].

2-3. Modification of starch structure

In the food industry, starch is used as a thickening or gelling agent, and the reaction of starch with proteins in food products plays a very important role in this regard. Starch naturally does not usually provide many of the needs and properties required for use in food. For example, the rapid retrogradation of some starches, or the loss of viscosity during the heating process or in an acidic environment, and even its high calorific value in the preparation of low-calorie foods are some of the weaknesses of natural starch. Therefore, in order to improve the quality of starch and increase its efficiency in different foods, depending on the need, individual changes can be made in its structure. Among these changes, we can mention the application of various physical, chemical, enzymatic, genetic or combined methods. Modified starches are used to improve physical properties, increase the stability of colloidal systems and create concentration. Starch modification is the concept of changing the structure of starch to improve its applications in different fields. These changes happen at the molecular level [25].

1-2-3. Chemically modified starches

Using chemical methods is the oldest and most common method of starch modification. In this method, special chemical groups such as ester groups, special ions, acetyl, etc. are placed on the starch molecules and create new properties in it, which can be called cross-linked starches, substituted starches, hydrophobic and hydrophilic starches (substitution of lipophilic groups), acidic starches and dextrin starches [29].

2-2-3. Enzyme modified starches

Hydrolyzing enzymes are usually used to change the structure of starch. Commonly used enzymes include alpha-amylase and beta-amylase, glucoamylase, isoamylase, pullulanase and cycloamylose-glucose-transferase. This process is performed on gelatinized starch and proper pH and controls are very important and necessary. In this method, glucoamylase enzyme is used to produce the desired starch, and its control is more effective and unwanted reactions occur less. This enzyme acts on the alpha 1 to 4 and alpha 1 to 6 bonds of starch and hydrolyzes it. If the action time is prolonged, the reaction will continue until the conversion of starch into dextrose. This type of starch is used in the production of baking products, snacks and desserts. Sometimes acid hydrolysis followed by enzymatic hydrolysis is used to change starch. The product of this method can be maltodextrin, glucose, fructose, sorbitol, mannitol, glutamate and organic acids such as citric acid, which is widely used in the food industry. The type of product produced is determined by measuring the amount of Dextrose Equivalent (DE). If the index (DE) reaches 100, pure dextrose and if it is around zero, natural starch is created. If (DE) is between 20-100, glucose syrup is formed, and if it is below 20, maltodextrin is formed [30].

3-2-3. Genetically modified or combined starches

Manipulating the level of enzymes involved in starch biosynthesis has made it possible to improve the quality of starch produced in plants such as potato, cassava, corn, wheat, rice and other materials containing starch. In order to change the physicochemical properties of starch with the help of genetic engineering solutions, interesting enzymes from various microbial sources are used so that they can apply the desired changes inside the amyloplast during starch biosynthesis. Silencing the genes involved in starch biosynthesis or increasing their expression has led to the production of starches with different physicochemical properties. Also, the production of biopolymers whose constituent units, other than alpha (1-4) and alpha (1-6), are bonds of alpha (1-3, 6) and alpha (1-4, 6) or a combination of these are connected, due to the importance of these biopolymers in the industry, it is currently among the important research fields today [31].

4-2-3. Modified starches by physical method

Modification of starch with the help of physical methods and without the use of chemicals has gained a lot of fans today, among its different types, we can mention oxidized starch, thermal-moisture starch, and pregelatinized starch [32].

3-3. Pregelatinized starch

It is a starch that has been heated in hot water until its granules swell and burst, and then it is dried by a suitable method, such as using roller dryers or spray dryers. In this method, the amount of gelatinization can be controlled by choosing the operating conditions, including temperature, time, amount of water, amount of starch. This type of starch has a higher viscosity, a favorable smell and color, and a higher transparency. The special feature of this type of starch is that it quickly absorbs water and shows its properties without applying heat. Although natural starches are available in adequate amounts in food products, in the modern food industry with a wide variety of products, it is necessary that starch can withstand a wide range of processing techniques, production, storage and distribution methods, which it is achieved by modification of natural starch by a variety of chemical, physical, enzymatic methods or a combination of these methods. One of the types of modified starches are pregelatinized starches, which are obtained through physical modification. In this method, the amount of gelatinization can be controlled by choosing the operating conditions, including temperature, time, amount of water and amount of starch. This type of starch has a higher viscosity and has a favorable color and better transparency. Puffing as one of the important unit operations can be used to convert the starch of all kinds of cereals into a pre-gelatin state. Puffing is actually a process that is carried out as a result of the sudden release of water vapor and the expansion of the pre-gelatinized kernel in the cereal grain containing starch [33]. Pre-gelatinization and puffing of various types of flour can be used in various products, including; Cakes, desserts, sweets, baby food, soups, stews, crackers, noodles, puddings, bread, etc. are used. Factors such as types and content of amylose, protein, amount of moisture and degree of gelatinization can have a significant effect on the quality of puffing of the product [34]. One of the influential parameters in puffed products such as pasta or gels containing starch is the ratio of amylose to amylopectin. Four important processes in the production of these products include; Gelatinization of the starch will be followed by cooling, drying and finally expansion. Puffed products have two main criteria for consumption, one is lightness and the other is product transparency, both of which are related to the structure of air cells and the degree of expansion and in fact, puffing is a process that takes place for the development of food products that have the right texture in terms of the characteristics of light or transparency, the presence of air, and crispness [35].

In the research conducted by Taghinia et al. (2015), rice bran pretreated with heat and ultrasound replaced wheat flour in the production process of Barbari bread at levels of 0, 5, 10 and 15%. The rheological properties of the dough and the textural and sensory characteristics of the bread were investigated. The results showed that the water absorption, development time and degree of dough softening increased, but its stability decreased. The moisture content of bread and the L* index of the crust also showed a significant increase. The texture of treatments with 10% pretreated bran was softer than the control sample 3 hours after cooking, but no significant difference was observed between the texture of treatments with 5 and 10% and control samples 48 hours after cooking. Finally, sensory evaluators identified the sample with 10% pretreated rice bran as the best sample [36].

In another research, examining the changes in the properties of normal and pre-gelatinized flour using a scanning electron microscope showed that the structure of normal corn flour was coherent, while the structure of the granules of pre-gelatinized corn flour was destroyed due to the microwave thermal process and it had more expansion and inflation. It was also found in manufactured bread, the sample containing pre-gelatinized corn flour had the highest amount of porosity (16.5%) and the lowest stiffness of the tissue in the period of 2 (9.7 newtons) and 72 hours after baking (17.2 newtons) [37].

Table 3- Types of starch modification methods

Modified starch	Aim	Advantages and applications
Transverse modifications	Expansion of starch granules	Increased resistance to thermal process, acid and stirring - use in sauce, soup and canned products
Stable	Preventing the shrinkage of starch granules	Increasing cold resistance - use in frozen products
Dextrin	Arrangement of starch molecules after breaking down	It can be used in much more quantities than natural starch - use in bakery and confectionery products
Enzymatic	Production of different gels with viscosity and thermal resistance	Improvement of textural properties - use as a flavor transfer agent
Acidic	Production of gels with lower viscosity and greater strength	Improving textural properties in high concentrations of starch - use in pastilles and jellies
Oxide	Affecting carbonyl and carboxyl groups	Production of durable and soft gels - use in confectionery products
Hydrophobic and hydrophilic	Creation of hydrophilic and hydrophobic groups	Emulsion stabilizer - use in drinks and salads
Thermal-moisture	Creating more solubility than natural starch	More resistant to digestive enzymes - Use as an improver
Pre-gelatin	The formation of pre-baking starch and creating the appropriate concentration	Use in all kinds of sauces, desserts, sausages and bakery products

4. Conclusion

In the normal heating method, materials are heated by transferring heat from hot points to cold points, which leads to a gradual increase in temperature. In the microwave heating method, with rapid changes in the direction of the magnetic field, severe vibrational oscillations are created in the bipolar molecules and ions, and when these molecules collide with each other, the temperature of the food increases rapidly. On the other hand, the rapid heating of food from its internal parts during the thermal process in the microwave itself is an effective factor in reducing energy loss and process time. Since every food process can cause changes in the structure of its constituent compounds, investigating the effects can be useful in interpreting and explaining the quality changes of food products resulting from different processes and justifying the suitability of the processes for use in the preparation of different food products. The special ability of heating in the microwave method has made it beneficial for use in domestic and industrial applications such as baking, baking, melting, blanching, dehydrating, pasteurization and sterilization, and even microwave radiation is one of the methods used to modify starch or parts of starch granules.

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Identifying the impact of earthquakes on the city form and providing solutions based on the smart city to make decisions due to potential incidents (case example: Tehran)

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ABSTRACT

The relentless threat of earthquakes in urban environments, particularly in seismically active regions like Tehran, necessitates the development of robust earthquake resilience strategies. This study was undertaken to assess how earthquakes impact urban form and to explore smart city solutions that enhance decision-making capabilities in anticipation of seismic events. By with structured questionnaires targeting urban planners, civil engineers, and technology experts, the research mapped out high-risk zones and gathered expert opinions on current preparedness and technological potential. The methodology involved a detailed analysis of Tehran's urban fabric, identifying areas at increased risk due to factors such as high urban density and outdated infrastructure. Additionally, data collected from questionnaires provided insights into the perceptions of preparedness and the perceived effectiveness of various smart technologies in improving resilience. Notably, the study revealed a moderate level of preparedness among urban professionals, with significant recognition of the benefits of smart technologies such as real-time data monitoring and infrastructure retrofitting, which were seen as pivotal in enhancing earthquake response strategies. Compared to previous works, this research introduces a combined with empirical insights from local experts to propose specific, actionable smart city solutions. The results advocate for a balanced approach to disaster management that combines traditional methods with advanced technologies, emphasizing the importance of proactive measures. Future work should focus on the longitudinal assessment of these technologies after implementation, further refining and validating the proposed solutions. The study underscores the critical need for cities like Tehran to adopt an integrated approach to urban planning that incorporates smart technology to bolster resilience against inevitable seismic challenges.

Keywords: Earthquake resilience, Smart city technologies, Urban planning, Seismic risk assessment, Tehran earthquake preparedness, Disaster risk reduction

1. INTRODUCTION

Urban centers globally are confronting complex dilemmas as they sprawl outwards and upwards to meet the needs of their expanding populations. This expansion is not merely a matter of physical growth but also encompasses the challenges associated with accommodating a larger number of inhabitants in ways that maintain—or ideally enhance—the quality of life and environmental sustainability [1]. A critical aspect of this urban evolution is the need to address the vulnerabilities posed by natural calamities, particularly in areas susceptible to seismic activities [2].

Earthquakes, for example, represent a formidable threat to densely populated urban regions, especially those situated in seismically active zones. The potential for significant loss of life, destruction of infrastructure, and economic disruption makes earthquakes a central concern for disaster risk management in urban planning [3]. The repercussions of such events highlight the acute need for cities to develop strategies that not only respond to disasters but also proactively mitigate their impact [4].

This urgency is underscored in the context of Tehran, Iran's sprawling capital, which is precariously perched on multiple seismic faults. The city's geographic and demographic conditions make it particularly vulnerable to earthquakes [5]. As Tehran continues to grow, both in population and infrastructure, its seismic risk potentially escalates, given the increased density and the complexity of its urban structures. This scenario presents a compelling case for reevaluating urban planning paradigms to integrate comprehensive disaster resilience measures [6].

Studying Tehran's approach to earthquake resilience and mitigation offers valuable insights into how urban areas can effectively integrate risk management into developmental planning. Such research is pivotal not only for Tehran but also for other cities facing similar threats, providing them with models and strategies to enhance their resilience against seismic disasters [7]. Therefore, enhancing our understanding of these dynamics is crucial for crafting policies that protect urban dwellers and their environments from the devastating effects of natural disasters.

In recent years, the convergence of urban vulnerability and seismic events has increasingly become a focal point for both academic researchers and policymakers. This heightened interest is driven by a growing awareness of the catastrophic effects earthquakes can have on densely populated urban centers [8]. Historical analyses provide a stark illustration of the devastating impacts that seismic activities can inflict, often leading to significant loss of human life and severe economic disruptions.

One poignant example is the 2003 earthquake in Bam, Iran, which resulted in the deaths of thousands and highlighted the severe vulnerabilities in both architectural and infrastructural frameworks. This tragedy demonstrated how underprepared urban environments are to cope with seismic disturbances. Buildings and other structures often failed, crumbling under the stress of the quake due to inadequate engineering and poor construction materials that were unable to withstand the seismic forces [9].

These seismic events serve as crucial case studies, underlining the urgent need for urban centers, such as Tehran, to develop and implement comprehensive strategies aimed at enhancing structural resilience. Such strategies are essential to mitigate the risks associated with earthquakes and to minimize potential damages. This involves not only reinforcing existing buildings and infrastructure but also adopting new technologies and approaches in urban planning and construction. Moreover, it necessitates a holistic view that integrates seismic risk management into the broader context of urban development and planning [10].

Through these measures, cities can improve their capacity to respond to and recover from earthquake events, thereby safeguarding both lives and economies. The lessons learned from past earthquakes can thus inform future efforts to create more resilient urban landscapes, where the risk of disaster is significantly reduced and the impact on human and economic capital is minimized. This transformation is crucial for enhancing the safety and sustainability of urban areas in seismically active regions [11].

The emergence of smart city technologies heralds a transformative potential for improving urban earthquake preparedness, an aspect increasingly critical in the face of global urbanization and climate change. Smart cities, by design, leverage advanced information and communication technologies to augment the quality and performance of urban services. This approach not only reduces costs and resource consumption but also significantly improves the interactivity between urban dwellers and governmental bodies [12]. Such enhanced connectivity and responsiveness are essential in fostering a more engaged and informed citizenry.

In the specific arena of earthquake risk management, the integration of smart technologies stands out as a vital tool. These technologies facilitate the collection of real-time data from multiple sources across the city, which can include sensors embedded in buildings to monitor structural integrity, mobile data from individual smartphones, and other IoT devices that contribute to a vast network of critical information. The capability to analyze this voluminous data in real time allows city planners and emergency services to identify and respond to potential risks with greater speed and accuracy [13].

Moreover, smart technologies enable more sophisticated analysis capabilities. Through the application of artificial intelligence and machine learning, data collected can be used to predict potential impact scenarios and optimize emergency response strategies. This predictive analysis is crucial not only for immediate responses but also for long-term urban planning and resilience building [14]. During crises, efficient resource management becomes paramount, and here again, smart technologies offer significant advantages. Automated systems can ensure that emergency resources are allocated more efficiently, prioritizing areas with the greatest need and ensuring that help arrives promptly. Communication technologies can also maintain information flow, keeping citizens updated with real-time instructions and alerts, which are crucial for minimizing panic and enhancing the overall effectiveness of the response [15].

Thus, the role of smart city technologies in enhancing earthquake preparedness is multifaceted, addressing not only the technological and operational aspects of crisis management but also the human elements of community awareness and resilience. This comprehensive approach promises not only to mitigate the effects of earthquakes when they occur but also to enhance the overall safety and sustainability of urban environments in the face of such unpredictable natural disasters [16].

Despite the promising prospects offered by smart city solutions in enhancing earthquake preparedness, their application in earthquake-prone regions has not been thoroughly investigated. Existing scholarly work has largely concentrated on traditional approaches such as seismic retrofitting of buildings and conventional emergency response strategies. These conventional methods focus primarily on physical reinforcements and organizational preparedness, often overlooking the potential synergies that could be developed with emerging technological innovations [17].

This oversight in the academic and practical realms underscores a significant deficiency in the current understanding of how smart technologies can be integrated into existing earthquake risk management frameworks. The traditional focus has resulted in a body of literature and practices that may not fully exploit the advantages of modern information and communication technologies in improving resilience and response capabilities [18].

For instance, cities like Tehran, which are highly susceptible to seismic activities, present a compelling case for the necessity of innovative research approaches. The capital city of Iran, Tehran, is situated on numerous fault lines, making it especially vulnerable to earthquakes. This situation necessitates a reevaluation of current risk management strategies and an exploration of how smart city technologies can be adapted to enhance structural and infrastructural resilience [19].

A comprehensive approach to this challenge would involve not merely assessing the physical vulnerabilities of such urban settings but also exploring how smart technologies could be implemented to address these risks effectively [20]. Potential areas of research could include the development of integrated sensor networks for real-time monitoring of structural health, data-driven simulation models to predict and manage the impacts of potential earthquakes, and intelligent evacuation systems that optimize emergency responses in real time during disasters.

This gap in the literature and practice highlights a critical need for interdisciplinary studies that fuse engineering, urban planning, information technology, and disaster management disciplines [21]. Such studies would provide a more holistic understanding of the potential of smart technologies in earthquake-prone areas and pave the way for their practical implementation, ultimately contributing to safer, more resilient urban environments.

This research endeavors to address the significant void in the current academic literature concerning the integration of smart city technologies within the framework of urban planning, particularly focusing on enhancing the resilience of Tehran against seismic activities [22]. Recognizing the vulnerability of Tehran, a city prone to seismic disturbances due to its geographical positioning, this study proposes a comprehensive, multidimensional approach to seismic risk mitigation.

The methodology combines three pivotal elements: geotechnical data, urban morphology analysis, and the application of smart technologies [23]. By collating and analyzing geotechnical data, the study seeks to understand

the underlying soil properties and geological features that influence the city's seismic resilience. Urban morphology analysis, on the other hand, examines the spatial configuration and structural characteristics of the city, identifying critical areas that require intervention to withstand earthquakes [24].

Furthermore, the study explores the potential of smart technologies—such as IoT sensors, real-time data analytics, and advanced communication systems—to enhance the city's responsiveness and adaptability during seismic events [25]. By integrating these technologies into the urban fabric, the project aims to develop an intelligent, responsive urban planning model that not only mitigates the risks associated with earthquakes but also enhances overall urban resilience.

In essence, this study not only seeks to fill a critical knowledge gap but also aims to provide actionable insights and frameworks that can be utilized by policymakers and urban planners in Tehran and other seismically active regions around the world [26]. Through this holistic approach, the research aspires to contribute substantially to the field of urban resilience, making cities safer and more adaptable in the face of natural calamities.

2. METHOD

This study employed a cross-sectional survey design to analyze the integration of smart city technologies into Tehran's urban planning for earthquake resilience. The participants consisted of urban planners, civil engineers, emergency management officials, and technology experts who are actively engaged in urban development and disaster management within Tehran. A total of 120 participants were selected using purposive sampling to ensure a comprehensive understanding of the challenges and opportunities related to implementing smart technologies in earthquake-prone urban settings. The demographic characteristics included 70 males and 50 females, with ages ranging from 30 to 60 years, representing a broad spectrum of experience levels and professional backgrounds. The GIS software utilized allowed for detailed spatial analysis and visualization of data layers such as population density, existing infrastructure, and seismic hazards.

A structured questionnaire was developed to collect data from participants about their perceptions of the current urban planning strategies and the potential for integrating smart technologies. The questionnaire included both closed and open-ended questions to capture quantitative and qualitative data respectively. Sample questions included:

- "Rate the adequacy of current earthquake preparedness measures in Tehran on a scale of 1-5."
- "Describe one smart technology solution that you believe could significantly enhance earthquake resilience in Tehran."

The validity of the questionnaire was established through a pilot study involving 15 urban planning experts, and its reliability was confirmed with a Cronbach's alpha of 0.89.

Participants were recruited through professional networks and relevant governmental and non-governmental organizations in urban planning and disaster management sectors. Data collection was conducted over three months, involving both online and face-to-face methods to accommodate the preferences and availability of participants. Each participant was briefed about the purpose of the research and the confidentiality of their responses before administering the questionnaire. Data from the GIS analysis were used to identify high-risk zones and potential areas for the implementation of smart solutions. Statistical analyses of the questionnaire responses were performed using SPSS. Descriptive statistics were used to summarize demographic data and responses to closed-ended questions, while thematic analysis was employed for open-ended responses to identify common themes and insights related to smart city technologies.

3. RESULT

This study aimed to evaluate the integration of smart city technologies into Tehran's urban planning to enhance earthquake resilience. The findings, derived from a detailed analysis involving Geographic Information Systems (GIS)

and structured questionnaires, offer crucial insights into the current state of preparedness and the potential benefits of advanced technologies in mitigating earthquake risks.

The questionnaire was distributed to the selected participants, who were given four weeks to complete and return it. Upon collection, questionnaire responses were encoded and analyzed. GIS data were then overlaid with the results from the questionnaire to identify alignment or discrepancies between data-derived risk assessments and expert opinions on feasible interventions.

The final stage involved synthesizing the GIS and questionnaire findings to formulate recommendations for integrating smart technologies into Tehran's urban planning practices. This comprehensive approach ensured that the recommendations were data-driven and aligned with expert insights, thereby enhancing the applicability and effectiveness of proposed smart solutions.

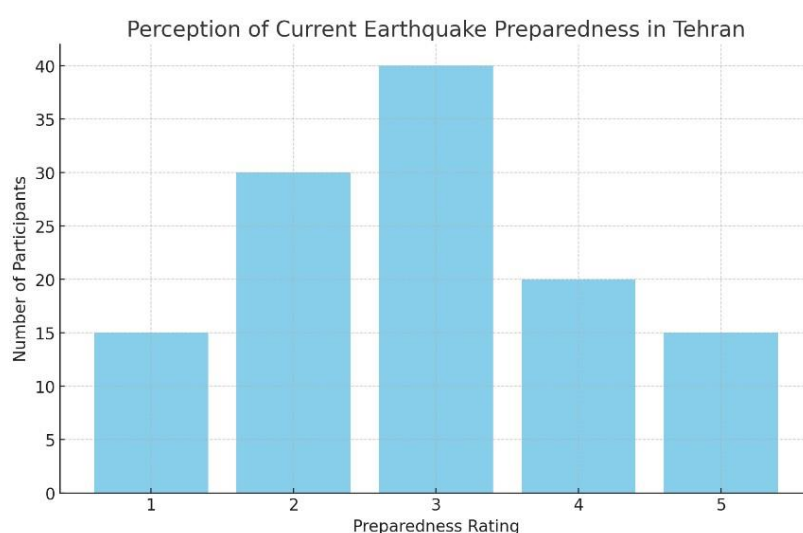


Figure 1 perceptions of current earthquake preparedness in Tehran is showing.

Figure 2 shows how participants rated the current earthquake preparedness in Tehran. The ratings are categorized from "Very Inadequate" to "Very Adequate."

Figure 3 illustrates the perceived effectiveness of smart technologies in enhancing earthquake resilience, with categories ranging from "Not Effective" to "Very Effective."

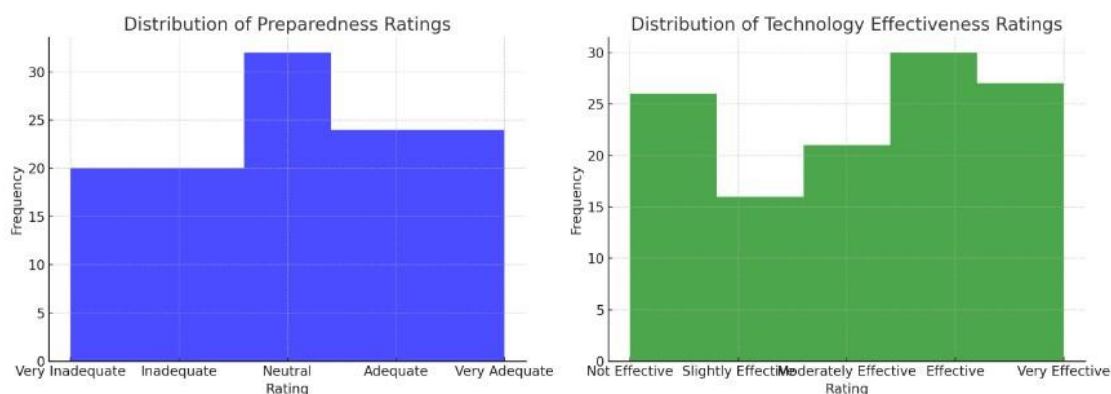


Figure 2 The rated the current earthquake preparedness in Tehran by participants AND the perceived effectiveness of smart technologies in enhancing earthquake resilience

These visualizations help in understanding the general sentiment among participants regarding both the current state of earthquake preparedness and the potential benefits of implementing smart technologies in Tehran.

As shown in Table 1, the effectiveness ratings for various smart technologies indicate a positive outlook among participants on their potential impact. Infrastructure retrofitting and real-time data monitoring received the highest effectiveness ratings, suggesting these are considered the most promising technologies for enhancing resilience.

Table 1 The effectiveness ratings for various smart technologies

Smart Technology	Average Effectiveness Rating (out of 5)
Real-time Data Monitoring	4.3
Automated Emergency Responses	4.1
Infrastructure Retrofitting	4.7
Public Alert Systems	4.0
Seismic Reinforcement Materials	4.5

An unexpected finding from the study was the relatively high rating of seismic reinforcement materials, which participants perceived as nearly as effective as more technologically advanced solutions like real-time monitoring. This underscores a potential underestimation of traditional materials and techniques in the discourse on smart earthquake resilience.

Systematic Description of Findings highlighted those areas with dense, outdated infrastructure are most at risk, providing a targeted focus for urban planning efforts.

The results obtained from this research provide a comprehensive overview of the potential areas for improvement in Tehran's earthquake preparedness and response strategies. While the effectiveness of smart technologies is generally

recognized among experts, the continued reliance on and respect for traditional reinforcement methods was an unexpected dimension that could influence future urban planning and policy-making. These findings contribute to a nuanced understanding of urban resilience, blending modern technological solutions with conventional approaches to form a robust defense against earthquakes.

4. CONCLUSION

This study has critically evaluated the integration of smart city technologies into Tehran's urban planning to enhance its resilience against earthquakes. By conducting a thorough GIS analysis and gathering insights through structured questionnaires, we have provided a clear picture of the current state of earthquake preparedness and the potential of various smart technologies to mitigate risks. The findings confirm a moderate level of preparedness and highlight significant opportunities for improvement through technology-enhanced interventions.

An unexpected yet valuable discovery was the high regard for traditional seismic reinforcement materials alongside advanced technologies. This underscores the importance of a balanced approach that incorporates both innovative solutions and proven methods, ensuring comprehensive urban resilience strategies that are both forward-looking and grounded in practical realities.

The integration of smart city technologies in earthquake-prone areas represents a significant step forward in urban planning. It leverages the power of modern technology to enhance traditional disaster preparedness and response strategies, offering a model that could be replicated in other high-risk cities globally. This study acts as a call to action for cities like Tehran to fortify their defenses against earthquakes during periods of calm.

Looking to the future, further research should explore the long-term impacts of these technologies on urban resilience, examine the socio-economic barriers to their implementation, and evaluate their effectiveness post-deployment. Such studies will not only refine the strategies proposed here but also challenge urban planners and policymakers to think critically about the integration of technology in disaster management.

In conclusion, this research fills a crucial gap in our understanding of urban earthquake resilience, proving the importance of smart city technologies in enhancing preparedness. By linking these findings to broader urban planning and disaster management discourses, this study contributes significantly to ongoing efforts to make cities safer and more adaptable in the face of natural disasters.

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Advances in Sustainable Architecture and Energy Efficiency

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Abstract

The importance of energy-efficient buildings seems to be essential due to the rapid depletion of energy resources, energy shortages, and increasing environmental pollution. Innovative methods are essential to reduce energy consumption. The construction industry is one of the largest energy-consuming sectors. In modern buildings, significant energy is used to maintain the tranquility of the building environment. In developing countries such as India, population growth, increasing standards of living and urbanization lead to an increase in building construction activities. To achieve the collective goals of energy security and environmental protection, environmentally sensitive buildings that use their resources wisely, minimize their greenhouse gas emissions, and have efficient waste management systems must be considered and designed. The options available in architectural intervention, building materials, and design methods should be carefully evaluated to minimize energy consumption. Overall, the studies reviewed show the importance of sustainable architecture and building materials in creating climate-resilient infrastructure. They highlight the potential to reduce greenhouse gas emissions, improve energy efficiency, and increase the comfort and well-being of residents through the adoption of sustainable building practices. The findings of the survey provide insights into sustainable building practices that can determine policy decisions and guide the development of climate-resilient infrastructure in the future.

Keywords: sustainable architecture, green building materials, energy efficient buildings, weather and weather ..resistant substructure, super concrete with high performance

1. Introduction

Sustainable building has become a key issue for many developing and developed countries in the 21st century. The world's population is expected to increase from 7.7 billion in 2019 to 9.7 billion in 2050 and reach more than 10.9 billion by the end of this century [1]. This increase in the world's inhabitants will increase the demand for water, energy, and natural resources, respectively, which will overwhelm biological systems and gradually degrade nature as energy use expands, resulting in an overall impact on the built environment. Previous studies have shown that buildings are the main key to energy consumers. It consumes the most energy, with the building sector accounting for about 30 to 40 percent [2]. In addition, more than one-third of all greenhouse gas emissions, which are a critical contributor to global warming and climate change, produce waste and potentially harmful atmospheric emissions. Therefore, achieving sustainability in buildings is a way to objectively reduce these negative effects.

Sustainability in buildings is a concept that has multidimensional pillars, including environmental, economic, social, ecological, technical, and technological aspects. Green and sustainable buildings can help reduce the effects of buildings on the environment, economy, and society. In addition, achieving sustainability in buildings by reducing greenhouse gas emissions with embodied energy through the use of natural resources, emissions of pollutants, recycling of materials, ensuring building safety, and meeting indoor environmental quality requirements. Some researchers and academics defined sustainable buildings as green buildings that are better able to reduce greenhouse gas emissions than conventional buildings and can achieve the commitment of net-zero carbon buildings. However, energy efficiency should be considered as a fundamental concept to achieve sustainable buildings, green buildings, energy-efficient buildings, ultra-low energy buildings. and zero-energy buildings[3].

To achieve sustainability in buildings, high energy efficiency must be achieved by reducing environmental impacts through energy performance benchmarking methods, energy-saving measures, integrating wind turbines into high-rise buildings, an integrated approach using multi-objective search, energy modeling and overall heat transfer value calculations, integrated building photovoltaic facades, lighting fixtures, high-performance building coverings.,

building materials with efficient resources, and innovative energy concepts[4].

The economic effects can be achieved by achieving cost savings and operational cost reduction (hard and soft costs) by using life cycle assessment, developing cost-benefit analysis, applying green price premiums, applying an optimal design method for multi-energy systems in buildings such as photovoltaic (PV) power generation system, solar water heating system and seasonal cold storage by minimizing the total cost. Life cycle reduced [5 and 6].

With the Industrial Revolution and technical-technological advances in the field of vernacular architecture, all parts of the world, which arose due to the nature around it and in harmony with the climate, were forgotten. Modern architecture, which was born of these developments, completely ignored the context of the formation of architecture. Modern man with the slogan of "domination over nature" fueled the crises of development more than ever. Our cities, our technology, and our architecture create the illusion in our minds that we are controlling nature while we are in control of nature and a part of it. The 1970s can be considered the decade of becoming aware of the crisis. Sustainable architecture is the result of a deep knowledge of the surrounding environment. In this architecture, quality is in line with one goal, which is comfort. The important point that is considered in this type of architecture is that all the factors involved in comfort are related to each other and are considered as a single system. Through architecture, society can be made aware of the desirability and abundant economic and environmental value of energies that are called harmless, green, calm, etc. It has become famous to inform that the energies that can be called beautiful from the point of view of artists and architects, the future of the world lies in beautiful energies. Therefore, we must discover the beauty hidden in the pure and vibrant energies. Overall, this review article aims to provide a comprehensive understanding of recent advances in sustainable architecture and building materials for climate-resilient infrastructure. By shedding light on the latest developments, challenges, and opportunities, this article aims to inspire further research and promote the adoption of sustainable practices that can help create a more resilient and environmentally friendly environment.

2. Literature Review:

This review checks and searches for relevant articles based on relevant keywords. Research papers published in reputable scientific journals based on the Google scholar database and ScienceDirect have been mainly reviewed since 2000 with topics focused on the research title and keywords including sustainable architecture, green building materials, energy efficient buildings, weather-resistant infrastructure, and ultra-high-performance concrete. In the article, we have focused on sustainability in architecture, sustainable design principles, and energy efficiency.

- Sustainability in architecture

The World Commission on Environment and Sustainable Development has defined sustainability as meeting the needs of the present without compromising the ability of future generations to meet their own needs. The optimal use of non-renewable energy sources is important not only from an economic point of view, but also from an environmental point of view. Although maintaining and strengthening economic institutions is vital in achieving sustainable development, it is our duty to preserve the environment for the present and future generations.

Architecture is one of the most prominent forms of economic activity. It has been suggested that the intensity (consumption) of architectural resources (the ratio of per capita consumption of architectural resources to per capita income) generally follows a pattern. The economic development of a country requires the construction of more companies, formal and residential buildings.

- Sustainable development and architecture in the construction industry

Sustainable development and architecture in the construction industry is a new phenomenon. According to the predictions about 75% of the world's population tends to live in cities. Therefore natural resources should be used in a way to maintain their sustainability to provide the required facilities. On the other hand architecture is clearly one of the largest manifestations of economic activities in a country. Economic development of a country into a factory will require more office buildings and residential buildings. For a family, the growth of financial income leads to a kind of attraction and desire to own and own a larger house with more expensive building materials, furniture, and household appliances, creating more comfortable temperature conditions in the interior spaces of the house, garden, or larger yard.

Architecture is one of the most prominent forms of economic activity. It has been suggested that the intensity (consumption) of architectural resources (the ratio of per capita consumption of architectural resources to per capita income) generally follows a pattern. The economic development of a country requires the construction of more companies, official buildings, and residential.

-Sustainable Design Principles:

In general, the goals of sustainable design in the framework of sustainable development emphasize the simultaneous protection of the natural environment and the man-made environment. Based on the views of theorists, the following three principles can be briefly introduced as the three principles of sustainable design from a technical point of view:

In short, the principles of sustainable development in relation to environmental sustainability include paying attention to the use of renewable resources, less use of non-renewable and polluting energies, meeting the basic needs of humans and society and creating a healthy environment for future generations, paying attention to the environment and reducing pollution, as well as paying attention to environmental cycles. The manifestation of sustainable development in the field of the built environment is called sustainable architecture. What is considered in this article is the approach of sustainable architecture to environmental issues, although it is difficult to separate this issue from other economic, cultural, and social aspects. From the perspective of Richard Rogers, sustainable design aims to meet the needs of the future, without destroying the natural resources that remain for future generations.

Tawil mentions. According to Jong-jin Kim, the three principles of resource conservation, life-cycle design, and humane design are the topics of sustainable architecture.

It takes time to minimize energy consumption by all possible means. From another perspective, the available energy must be used wisely. No serious thought is given to using energy at an optimal level. Although it is very difficult to shorten the requirements, a new culture of energy conservation must be created. Energy efficient buildings are essential to reduce the energy burden and improve development, and also help support the economy of our country. It is useful. In this regard, the construction industry has played a vital role. Engineering has ushered buildings into a new era of this modern world. Today, buildings are designed with energy efficiency and sustainability in mind.

-Sustainable buildings

Sustainable buildings are buildings that are operated with the least consumption of natural resources without harming operations, services, and products. These buildings do not need to supply energy from external sources. Energy is produced and consumed on-site, which is the best option for the environment. Energy-efficient buildings are also sometimes called sustainable buildings or green buildings. Eco-friendly process for design, construction , maintenance, operation and renovation of energy-efficient buildings[11].

-Energy efficient buildings

Energy-efficient buildings are buildings whose design has been changed through architectural tools and a modified construction methodology is adopted, due to which the building is self-sufficient in terms of energy. However, there are always energy losses, but energy is retained inside the building, and less energy is required to operate the building, which provides the same level of comfort and living performance It does. High-quality building materials are used[12].

- Passive and low-energy buildings

Passive and low-energy buildings are where there are specific design criteria to reduce the operational energy consumption in a building. They are designed to significantly reduce the energy requirement for the ecological footprint of the building, improve the heating, ventilation and air conditioning of lighting, building cladding elements, etc., which depends on the passive solar design, high levels of insulation. The standards of good ventilation, controlled ventilation, high-performance glazing and efficient heating systems are designed. Building Cover A It is the main component in the structure of the building, separating the indoor and outdoor environment, and reducing heat transfer. Light cement with lower material density, lower thermal conductivity, and autoclave aerated concrete with the intrinsic nature of high porosity AAC result in superior thermal properties that reduce the heating and cooling load in the building cladding[13]. The roof is susceptible to solar radiation, thus affecting the comfort of indoor occupants as well as the temperature of the outside air in urban areas, accounting for 20 to 25 percent of all urban surfaces. In recent days, some passive techniques have been used to reduce the solar absorption of the roof, which include reflective/cooling solar roofs, partially or fully green roofs with vegetation, roof insulation, Evaporative roofs and photovoltaic (PV) roofs[14].Recently, gypsum wall boards with embedded PCM have been used to reduce the maximum internal temperature.Ground-to-air converters are used directly for heating and cooling the space in buildings. The temperature of the air at the outlet, the geological characteristics of the soil, the characteristics of the pipe related to heat exchange, and the climatic conditions of the site are some of the factors affecting the effectiveness of ground cooling systems. It reduces the electricity consumption of a typical building by between 25 and 30 percent. Cold night air is also used to cool the heat. absorbed by the building[15]..

The performance of these passive methods is highly dependent on climatic conditions, so an appropriate design strategy with a proper understanding of climatic factors should be used.

-General principles of energy management in building systems

Energy management in buildings can be studied according to several factors, including the location of the building, the building covering, and the building systems:

The choice of building location determines the weather conditions to which the building will be exposed. Building cladding determines the impact of local conditions on the occupants of a building. Building systems complement the heating and cooling power and accessible lighting of the surrounding environment. As far as the use

of these complementary systems is related to the building's cladding and its local features, energy consumption can be minimized. Kills. [16].

Buildings are closely related to air conditioning. This connection involves factors over temperature. Human comfort depends on humidity, the speed of air flow, as well as temperature. The absorption and waste of energy in buildings depends on these factors, as well as the speed of solar energy, the shade of trees or hills, the speed of the wind, and the length of the hot and cold seasons. In order to achieve stable buildings, insulation, the use of materials optical, selective layers, and radiation barriers [16].

Climatic divisions and typology of architecture

The diverse characteristics of each climate have a great impact on the formation of cities and the architectural structure of that region. Therefore, determining the accuracy of the climatic zones of different regions is very important in providing appropriate plans suitable for the climate of each region.

One of the critical issues in construction, residential and climatic architecture is heating them in the cold seasons of the year and cooling them in the warm seasons of the year to reach the limits of human heating comfort. As a result, considering special arrangements related to the shape, size of windows, the nature of building materials, and weather conditions can lead to the greatest savings in heating and heating.

Cooling residential areas is a vital problem in understanding the architectural value of each period and each region knows how to adapt a building to the specific climate of that area. How the building uses the sun, breeze, and greenery, and how the architect creates a small climate. Another factor that reduces the impact of climatic factors on buildings is the size of the building. If we quadruple a shape, the ratio of its volume to its surface decreases from 1.6 to 1.15, and as a result of reducing the outer area to the covered volume, the impact of climatic factors is reduced. However, we can propose principles for buildings, which are as follows:

- 1) In cold regions, closed and compact forms and cubic buildings or adjacent buildings at the back are preferred along the north-south axis. In such areas, high-rise buildings are more suitable.
- 2) In temperate climates, it is easier and more free to choose forms, but by the way, forms are preferred along the east-west axis.
- 3) In hot and dry regions, solid and compact forms are recommended. Cubic forms or forms with a larger north-south side are better than their east-west side. High-rise buildings are also preferable to short buildings.
- 4) In humid areas, buildings that extend freely along the east-west axis are more suitable, but buildings that extend along the north-south axis are not suitable because they are exposed to intense solar radiation.

Simultaneous analysis of thermal comfort and energy consumption in the building

In order to predict the thermal comfort conditions in a building, as well as to analyze the performance of heating and cooling systems in terms of energy consumption and thermal comfort, so that a suitable ventilation system can be selected or the performance of these systems can be optimized according to the climatic conditions. Local conditions, traditions, and customs and existing limitations, the interior of a building must be modeled from a thermal point of view. [18].

In general, heating and cooling systems of buildings can be divided into two main categories: radiation systems and convection systems. Underfloor heating systems, as well as cooling and ceiling heating systems, are among the most important and practical radiant ventilation systems.

Due to the widespread use of central heating systems in Iran, it seems that optimization of these systems to achieve high efficiency and ultimately reduce costs and energy consumption is inevitable.

In general, in a central heating system, the energy-saving potentials can be summarized as follows:

- Prevent energy waste of central heating services and transportation machinery
- Reducing excess energy consumption by boilers and ancillary equipment
- Preventing unnecessary work of energy-consuming machines that lack an independent control system
- Using appropriate controllers to control heating [16].

- Methods of optimizing energy consumption in ventilation systems of buildings

- 1) Minimizing the uptime of ventilation equipment by installing educational placards
- 2) Minimizing ventilation equipment uptime by entrusting the task of turning ventilation equipment on and off to reliable staff
- 3) Minimizing the uptime of ventilation equipment by installing adjustable thermostats or space controllers
- 4) Minimizing the operation time of ventilation equipment by installing timed disconnects.

-Electrical energy saving techniques

The lighting system is one of the most important consumers of electrical energy. Of the total electrical energy consumed in the lighting system, 63% is allocated to formal buildings, 22% to residential buildings, and 12% to streets and roads.

The lighting system is used to illuminate different places. This system converts electrical energy into light. A lighting system consists of an electrical part and a non-electrical part and has different parts such as power supply, launch equipment, ballast control, lamps, and light (Sharif 2006). Lighting system design means determining the number and type of lamp for a specific place. In such a way that the intensity of lighting in that place is sufficient for the intended purpose.

The steps of an energy consumption management plan for lighting systems are as follows:

- 1) Measuring the size of current brightness levels
- 2) Proper Daylight Use
- 3) Improvement Suggestions with Existing Equipment
- 4) Evaluation of alternatives and installation of new equipment.

-Technical Tips for Sustainable Building Design

From an environmental perspective, paying attention to climate and lifestyle is a good way to meet architectural needs and achieve a holistic vision for design. To achieve successive successes, designers need to increase their knowledge of new design philosophies and the relationship between interior and exterior spaces. The relationship between form, structure, and comfort depends on the characteristics of the building's orientation, location, and education. The application of sustainable design in architecture has been proposed.

-Methods for applying sustainable design in architecture

• Energy Saving

Energy conservation is one of the methods of reducing inlet discharge. The main goal of this technique is to reduce the consumption of fossil fuels. Buildings not only consume energy when they are used for heating, cooling, and lighting purposes, but they also consume energy during construction. Consumables in architecture are first extracted and harvested from raw materials, then they go through the production process, and finally they are transported to the building site. In the construction phase, a lot of energy is used for various activities from excavation to welding.

• Energy-Based Planning for a Site

Such planning enables the designers to make the most of the natural resources available on the site. In temperate weather, the creation of pores on the south side of the building increases passive solar heating. Deciduous trees shade in the summers and make it possible to receive the sun's heat in the winters. By planting evergreen plants on the north side of the building, it can be protected from winter winds and Improve its energy efficiency. To provide natural cooling conditions in summer, buildings can be placed near water sources on site .

This important prerequisite is often overlooked in the design of modern buildings. The passive architecture of the solar system provides us with solutions and arrangements so that we can use the sun's radiation at more useful times of the day. By creating shade with the help of canopies or plants, it is possible to avoid receiving heat in the summer and subsequently the costs imposed for ventilation services. Wind or airflow has been an important advantage among the major issues of urban planning[16].

- **Insulation:**

The windows are highly efficient and the walls are insulated and prevent heat from being received and wasted. Reducing such heat transfer reduces the amount of heating and cooling charge of the building, thereby reducing energy consumption. Lower heating and cooling costs require smaller ventilation systems. These tangible and objective advantages, highly efficient windows and insulated walls provide more suitable heating conditions in practice. Due to the characteristics of insulating materials, the degree of heating of windows and walls is higher in winters and less in summers. The use of smaller ventilation equipment reduces the noise of mechanical machines and increases the sound quality of interior spaces..

-Progress in energy-efficient buildings for new and old buildings

Population growth and increasing energy demand have both led to major increases in energy consumption. Currently, buildings account for more than 40% of the world's energy consumption and 33% of global greenhouse gas emissions. Numerous studies have shown that EEBs provide a prospect for financial savings while also reducing greenhouse gas emissions. Building ion automation, which has recently been added to the construction industry, can improve the comfort of occupants, the efficiency of building systems, and reduce energy consumption and operating costs. Automation has been achieved with a variety of tools, including mechanical, hydraulic, pneumatic, electrical, electronic, and computers, commonly known in combination as smart building automation system. Unlike ion automation, it is not easy to install energy-saving and environmentally friendly materials in older or built buildings. Implementation These materials are wiser in the design and manufacturing stage. Energy-efficient materials are more cost-effective and efficient.

-Silica aerogel blanket as an ultra-insulating material for the development of energy-efficient buildings

However , the cost of making them remains high, so the latest research efforts have focused on reducing the time and cost in the manufacturing process of super-insulating materials such as silica aerogel .Due to these drawbacks, more studies are underway on how to create an effective alternative to silica aerogel[20].

Since aerogel blankets are highly porous materials and water vapor can pass through the pores, so the factor of " μ water vapor diffusion resistance" was selected as the main parameter for this study. This shows the relative value of the water vapor resistance of the product and an equally thick layer of still air at the same temperature. Here is the μ value for the aerogel blanket remaining 5.5 -2.8. for insulation materials. Thermal is acceptable. Conventional mineral wool has $\mu = 1-3$ and organic insulators have $\mu = 60-150$. [20]..

Table 1 - Basic properties of aerogel blankets.

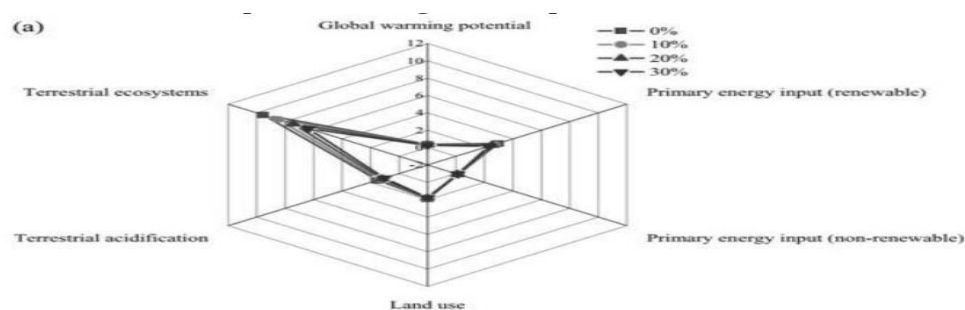
Needle Glass Fiber Aerogel Blanket	Wool Needle Glass Fibers	Silica Aerogel	Properties
150	150	Granular	Length (mm)
8	%6	x	Thickness
4%	%4	x	Fraction Volume
			Iliaf
15-17	31	15-14	Thermal
			Conductivity
			(Mw.m-1. K-1)
150	100	100-100	(g. cm-3) Density
6/206	x	<20	Stability Khumsi
			(kPa)

Although residential structures still have the majority of potential. With a lower thickness, it can provide the same insulation as traditional insulation materials. In the future, aerogel blankets could be a viable alternative to traditional insulation. Although the concept is currently uncommon in underdeveloped countries such as Bangladesh, interest in GB (green building) is growing. Bangladeshi buildings, which are both commercial and residential, use nearly 32% of primary energy.

-Ultra High Performance Concrete (UHPC)

Ultra-high-performance concrete (UHPC) is a material that has gained traction in recent years for its exceptional mechanical properties, durability, and potential for sustainable construction. However, UHPC's high production costs and environmental impact have limited its widespread use in construction applications. The use of secondary aggregates in UHPC can improve the overall performance of UHPC, especially in terms of durability and sustainability, by reducing waste entering landfills and reducing carbon emissions associated with cement production, which is responsible for about 8% of global carbon emissions. Recycled materials can improve the microstructure of UHPC by reducing porosity and improving particle packaging density[21]. In addition, the use of recycled materials can improve the long-term sustainability of UHPC by reducing the need for virgin materials and conserving natural resources. One of the main challenges is the diversity of recycled materials. Therefore, it is important to carefully select and test recycled materials to ensure that they are suitable for UHPC production. UHPC with EGA has been found to have better mechanical properties than conventional UHPC and other secondary aggregates with compressive strength greater than 127 MPa and flexural strength greater than 21 MPa. In addition, the water absorption of UHPC with EGA was lower than that of conventional UHPC, indicating better durability and moisture resistance. Life cycle valuation of ultra-high-performance concrete with EGA also shows recognizable results from other secondary materials, showing a significant reduction in environmental impact compared to conventional UHPC[21].

The embodied carbon footprint of UHPC with EGA was approximately 16% lower than that of conventional UHPC. In addition, UHPC designed with 15% coral coral sand and 30% coral sand together showed comparable properties. Application of secondary aggregate in UHPC It has the potential to address the environmental and economic challenges associated with UHPC production while improving the yield and durability of the material. However, a careful examination of the quality and availability of recycled materials is essential to ensure that UHPC is suitable for specific applications. Figure 1 shows a comprehensive analysis of UHPC according to the embedded CO₂, compressive strength, and substitution level of various waste materials. [22].



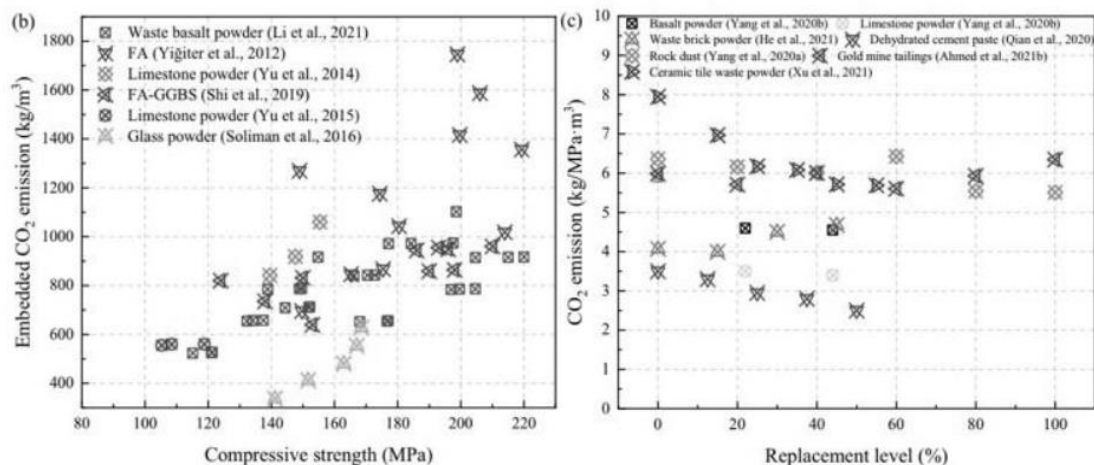


Figure 1---Environmental Benefits(a) and CO2 (b and c) Emissions of UHPC with Solid Waste

-Smart Materials

Intelligent materials are a new term for materials and products that have the ability to perceive and process environmental events and react appropriately to them. In other words, these materials are changeable and are able to change their shape, form, color, and internal energy in a reversible way in response to the physical or chemical effects of the surrounding environment. The first group, i.e. non-intelligent materials, do not have the above special feature, semi-intelligent materials are only able to change their shape and shape for a time or a short time in response to environmental influences, but in smart materials, these changes will be repeatable and reversible. Smart materials are also known as "flexible" and "adaptable" materials, due to their special feature in adapting to environmental conditions..

-Intelligent energy-saving materials

These materials store energy in the form of light, heat, hydrogen, or electricity. Intelligent heat-storing materials are the most popular in this group, which have an intrinsic feature that enables them to store energy in the form of heat or cold in the form of latent energy. The most widely used are under the category of transforming materials, which can act as a medium for regulating temperature. They change their state from liquid to solid by crystallization, releasing a certain amount of heat energy that they had previously stored at higher temperatures, and in reverse, by changing from solid to liquid at the time of the entry of heat energy, they keep the amount of heat or temperature constant (Figure 2)...

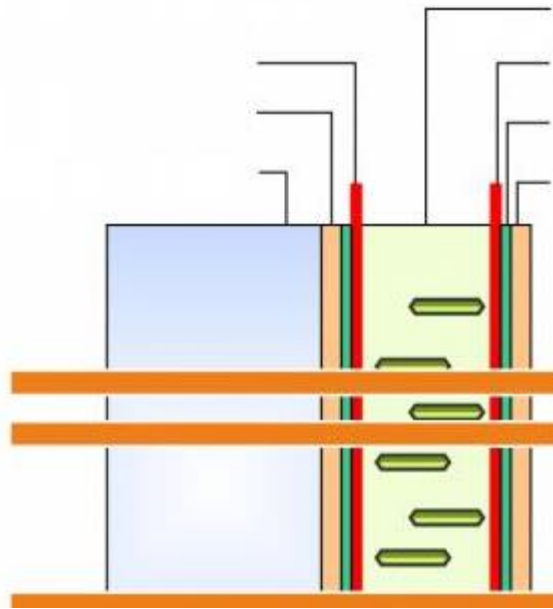


Figure 2. Smart glass with a layer of crystal liquid sandwiched between them

3. Discussion and Conclusion:

The use of the right amount of solid waste to replace traditional aggregates is beneficial for improving the performance of UHPC, which takes advantage of the uneven surface and water storage capacity of the aggregates. The use of secondary aggregates in UHPC has the potential to address the environmental and economic challenges associated with UHPC production while improving the yield and durability of the material. Solid waste replacement level 10% – 30% The potential value of global warming was 10.8% – 32.5%. Therefore, this could be a potential method for the future concrete industry. Careful attention to the quality and availability of recycled materials is essential to ensure that UHPC is suitable for specific occasions.

Future research should focus on developing standardized test protocols for recycled materials and investigating the long-term performance and durability of UHPC with secondary materials. Integrating energy-efficient design, passive strategies, and renewable energy systems into sustainable architectural practices can significantly reduce energy consumption and greenhouse gas emissions, while improving the performance of buildings in different climate zones. optimizes. The advancement of environmentally friendly building materials, such as recycled and biodegradable options, low-carbon concrete, and advanced insulation systems, contributes to climate resilience by minimizing environmental impact and increasing durability. However, the downside of these advanced applications, such as the emissions of greenhouse gases during the production of UHPCs, must also be considered.

Also, due to the fact that the resources available in the land for its inhabitants are limited and running out, therefore, it is very important and necessary to try to provide solutions for sustainable design and development in architecture. Research and Research on Materials Intelligent presents a new challenge for architectural designers. Smartening, and especially the use of smart materials and materials that react to environmental issues, facilitates the maintenance of buildings, increases the useful life of buildings, prevents excessive energy consumption, and more innovative architectural designs. The realization of architectural goals becomes sustainable.

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Seismic Risk Assessment of Urban Road Network

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ABSTRACT

Highways are an integral part of modern infrastructure, facilitating transportation and the movement of people, goods, and services. They enhance social connectivity by linking cities, towns, and rural areas and provide easier access to services and opportunities. However, the seismic vulnerability of urban road networks can lead to significant economic and social consequences. In this study, a proposed method for assessing the seismic risk of urban road networks is presented. The proposed method estimates the hazards of earthquakes caused by seismic wave propagation and soil liquefaction, along with the probabilistic combination of their occurrences. This method was applied for a case study in the southern region of Iran. The results indicated that in the event of an earthquake with a long return period, in addition to urban disruption, the city would suffer significant economic losses. The proposed method in this recent study facilitates not only qualitative assessment but also quantitative estimation. The proposed method and its outcomes can greatly assist urban decision-makers in enhancing urban resilience.

Keywords: Natural hazards, seismic risk assessment, transportation networks, seismic vulnerability

5. INTRODUCTION

Critical infrastructure is considered the backbone of society and the economy, playing a vital role in achieving economic and social well-being and sustainability. Urban highways, as critical arteries for transportation and intra-city communication, play a crucial role in facilitating the swift and efficient movement of vehicles. The significance of urban highways lies not only in facilitating public transport and reducing traffic congestion but also in ensuring safety and easy access to emergency and urgent services. However, these critical infrastructures can be affected by various natural hazards such as floods, storms, and earthquakes, which can disrupt their operations and lead to economic, social, and psychological consequences.

Earthquakes are one of the natural hazards that can severely damage urban highways [1]. Major earthquakes can cause visible damage, such as cracking, collapse, and even complete destruction of bridges, tunnels, and various sections of highway networks. The 1994 Northridge earthquake in California, the 1995 Kobe earthquake, and the 2011 Christchurch earthquake in New Zealand severely impacted major road networks, leading to significant transportation disruptions [2],[3]. Furthermore, when severe earthquakes occur, the need for rapid evacuation of urban areas becomes urgent, and this can be exceedingly difficult if highways are damaged. For instance, during the 2003 Bam earthquake in Iran, many urban roads suffered major cracks and complete destruction, disrupting key routes [4]. This incident created numerous obstacles for emergency responses and crisis management due to the disruption of the urban road network.

Given the diverse components of urban road networks, earthquakes can trigger a wide range of geotechnical phenomena, each causing damage in different ways. These hazards include the seismic waves propagation due to transient ground deformation (TGD), soil liquefaction, landslides, and ground surface rupture caused by permanent ground deformation (PGD), all of which depend on varying geographical conditions [5].

Identifying the vulnerabilities of urban road networks is a critical step in efforts to mitigate the impacts of earthquakes [6]. A straightforward approach to assessing seismic vulnerability involves post-earthquake observations.

Tang and Huang [7] examined the seismic vulnerability of urban road networks using fuzzy logic. Zhou et al [8], studied the consequences of urban road disruptions due to earthquake-induced landslides in Yangbi, China. One of the key methods for reducing earthquake damage is the seismic design of highways. This includes using earthquake-resistant materials, reinforcing the structures of bridges and tunnels, paving roads, and employing modern technologies for monitoring and evaluating the performance of structures during earthquakes. Various guidelines, such as those from the American association of state highway and transportation officials (AASHTO) and the federal highway administration (FHWA) have been developed for seismic assessment based on past research and experiences. These guidelines provide regulations for seismic analysis, the design of resistant structures, and methods for assessing the vulnerability of highways to earthquakes.

Despite significant advancements in the seismic design of highways, a substantial research gap remains in assessing the seismic risk of these infrastructures. Today, fragility curves, which probabilistically present the vulnerability of road networks to various earthquake intensities, have been developed [9], [10]. Many studies have focused on designing resilient structures [11], [12], but comprehensive seismic risk assessments, which analyze the various impacts of earthquakes on the overall performance of existing highways, have received less attention. In this research, we aim to examine the vulnerability of urban highways to earthquakes more comprehensively and accurately using modern seismic risk assessment methods and probabilistic analyses.

This study proposes a comprehensive framework for assessing the seismic risk of urban road networks. As a case study, the seismic risk of a highway in Shiraz was evaluated at a 975-year seismic hazard level using the proposed method. For this purpose, the potential effects of seismic wave propagation and earthquake-induced soil liquefaction were considered in determining the vulnerability values of the urban road network. The vulnerability of different sections of the highway was estimated both probabilistically and in terms of economic impact. Based on these results, the economic damage to the highway was calculated. Based on these results, the economic damage to the highway was calculated.

6. METHODOLOGY

This section presents a method for probabilistic seismic risk modeling that considers the combined earthquake hazards for urban road networks. The primary objective is to account for the combined effects of TGD and PGD due to soil liquefaction, which have the potential to cause significant damage to road networks. In this method, the combined probabilistic seismic damage to the components of the road network is assessed, and by quantitatively converting the seismic damage of each section of the road network into financial costs, economic losses are estimated. The proposed method consists of three main steps: 1) seismic hazard analysis, 2) seismic vulnerability analysis, 3) seismic loss analysis. The HAZUS guidelines [13] are utilized in the proposed method. **Fig. 1** illustrates the step-by-step process of the proposed method. The following sections provide a more detailed explanation of these steps.

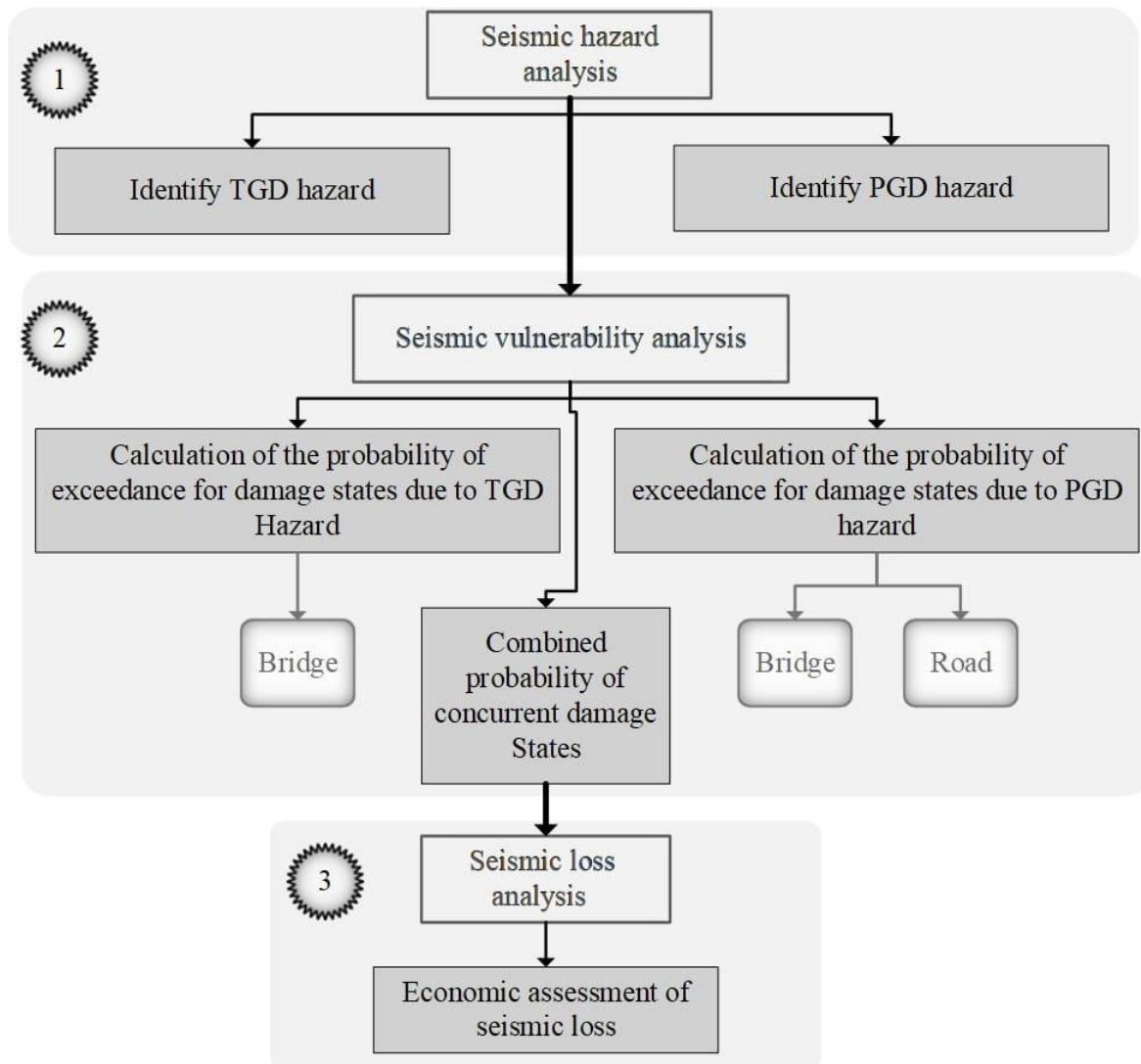


Fig. 1. Step-by-step framework for the proposed seismic risk assessment of road networks.

2.1 seismic hazard analysis

To estimate the seismic hazard analysis, the first step is to identify the seismic characteristics of the study area. Accordingly, the proposed method in this research begins by collecting seismic data, fault locations and their mechanism, and soil liquefaction susceptibility map. Following this step, a seismic hazard analysis is conducted to estimate the intensity of ground motion. Probabilistic seismic hazard analysis (PSHA) is considered suitable for this research due to its ability to account for the inherent uncertainties of earthquakes, such as uncertainties in location, time, and magnitude [14]. Based on equation (1), PSHA is performed by considering the geometric and seismic characteristics of the sources in the study area [15].

$$P(IM > x) = \sum_{i=1}^{n_{sources}} \lambda(M_i > m_{min}) \int_{m_{min}}^{m_{max}} \int_0^{r_{max}} P(IM > x | m, r) * f_{M_i}(m) * f_{R_i}(r) dr dm \quad (1)$$

where $\lambda(M_i > m_{\min})$, represents the rate of earthquakes greater than a minimum magnitude for each seismic source. The parameters $f_R(r)$ and $f_M(m)$ are the probability distribution functions of the distance to the earthquake occurrence and the magnitude of the earthquake, respectively, as used in the relations provided in [16]. The outputs of this analysis are strong ground motion parameters, such as peak ground acceleration (PGA) and spectral acceleration (SA), which are used as key parameters for identifying the hazards of TGD and PGD due to soil liquefaction. The HAZUS guidelines offer estimates for seismic hazard analysis related to TGD hazard in road networks, focusing on parameters like PGA and SA. For analyzing hazards caused by PGD due to soil liquefaction, HAZUS recommends using the region's soil liquefaction susceptibility map and applying the proposed equation (2) [17].

$$P[\text{Liquefaction}] = \frac{P[\text{Liquefaction} | \text{PGA} = \text{pga}]}{K_M \cdot K_W} * P_{ml} \quad (2)$$

Here, $P[\text{Liquefaction} | \text{PGA} = \text{pga}]$ represents the probability of soil liquefaction given the occurrence of a specific PGA. P_{ml} is the map unit sensitivity ratio for liquefaction for four categories: high, medium, low, and no sensitivity to soil liquefaction, which are 0.2, 0.1, 0.05, and 0, respectively. This equation (2) is presented for a moment magnitude of 7.5 and a groundwater level of 5 feet. By using correction coefficients K_m and K_w in equations (3) and (4), equation (2) can be applied to different magnitudes and groundwater levels [13].

$$K_M = 0.0027M^3 - 0.0267M^2 - 0.2055M + 2.9188 \quad (3)$$

$$K_W = 0.022d_w + 0.93 \quad (4)$$

The expected value of permanent ground displacement due to soil liquefaction can be expressed as a function of PGA based on equation (2).

2.2 seismic vulnerability analysis

The second step of the proposed method continues using the results obtained from the seismic hazard analysis step. The seismic vulnerability of each section of the road network can be calculated using the fragility curves provided in the HAZUS guidelines [13]. Each section of the road network has specific damage states, which are typically defined as no damage, slight damage, moderate damage, extensive damage, and complete damage [13]. Each of these damage states has a specific definition. The probability of exceeding each damage state, assuming a lognormal distribution, is obtained from equation (5).

$$P[Ds \geq a = ds_i] = \Phi\left(\frac{\ln(\text{mean}_a) - \ln(X)}{\beta_a}\right) \quad (5)$$

The parameter mean_a represents the mean value of ground motion intensity for each damage state, while β_a denotes the dispersion factor for the same damage state. After estimating the probability for each damage state, assuming the independence of TGD and PGD hazards, the combined probability of these events is obtained using equations (6) to (8) [13].

$$P_{\text{comb}}[ds \geq DS_i] = P_{GS}[ds \geq DS_i] + P_{GM}[ds \geq DS_i] - (P_{GS}[ds \geq DS_i] * P_{GM}[ds \geq DS_i]) \quad (6)$$

$$P_{\text{comb}}[ds = DS1] = 1 - P_{\text{comb}}[ds \geq DS1] \quad (7)$$

$$P_{\text{comb}}[ds = DSi] = P_{\text{comb}}[ds \geq DSi] - P_{\text{comb}}[ds \geq DSi + 1] \quad (8)$$

2.3 seismic loss analysis

The final step of the proposed method involves quantifying the damage to various components of the road network and calculating the seismic losses. The seismic damage to the road network depends on the location of the components and the intensity of the strong ground motion experienced by different sections. According to the HAZUS guidelines [13], the economic loss (EL) for each component of the network is equal to the product of the total damage ratio (DR_i) and the replacement cost (RV) of that component, as given by equation (9). It is also worth noting that the damage ratio is equal to the sum of the damage ratios for each damage state multiplied by the probability of that damage state occurring, as shown in equation (10).

$$EL_n = DR_i * RV \quad (9)$$

$$DR_i = \sum_{i=1}^4 \sum_{k=1}^{k=n} (DR_i * P_{comb}[ds = DSi]_k) \quad (10)$$

where EL_n , k and n represent the economic loss for a specific component, the number of components in the road network and the number of damage states, respectively.

7. CASE STUDY

This section presents a case study to evaluate the practical application of the proposed method. The case study focuses on an urban highway in Shiraz, located in southern Iran. The following details outline the steps of the proposed method as applied to this case study.

3.1 seismic hazard analysis of case study

In the first step of this section, seismic data of the study area is required. The study area is generally located within the southern Zagros region, which is an active seismic zone due to the presence and interaction of the Eurasian and Arabian tectonic plates [18]. Additionally, active faults such as the Sabz Pushan and Sarvestan contribute to the seismic activity of the region. Examples of significant earthquakes in this area include the 6.6 magnitude earthquake in 1972 and the 5.8 magnitude earthquake in 2021.

In this research, the Rahmat highway in Shiraz is considered as the case study. The Rahmat highway begins in the southwestern part of Shiraz, near Shahid Dastgheib airport, and extends to the eastern part of the city. This highway passes through several key areas, including residential neighborhoods, commercial districts, and recreational areas, making it a crucial thoroughfare in Shiraz. Along its route, which is approximately 11 kilometers long and selected for this study, there are also three major bridges. Fig. 2 shows the studied highway, including its length and the bridge components along the highway.

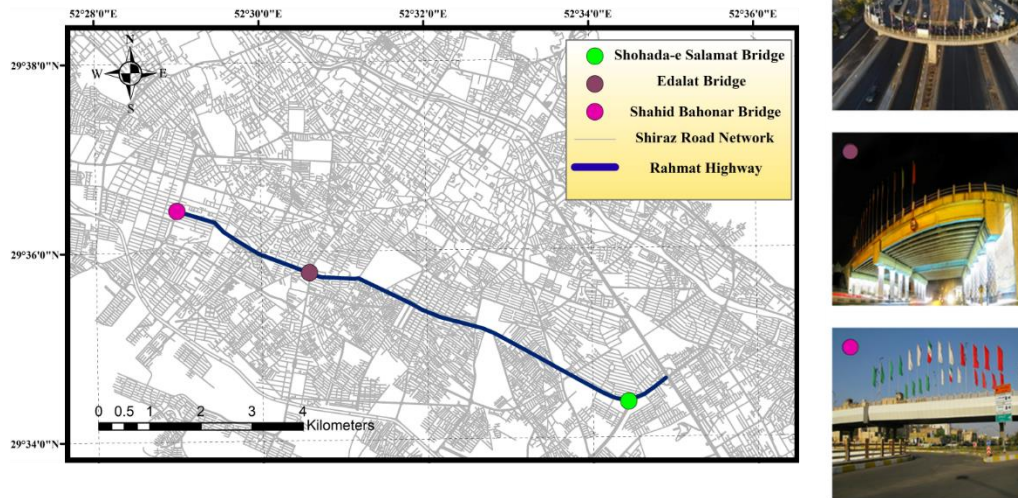


Fig. 2. Network components of the studied highway.

In the seismic hazard analysis section of this study, the results from the research conducted by Alavi et al. [19], which assessed the hazard of TGD and PGD due to soil liquefaction, were used. In their study, they evaluated the strong ground motion parameters such as PGA and SA, as well as the PGD due to soil liquefaction, for four seismic hazard levels in southern Iran, focusing on the city of Shiraz. This study utilizes the results of the mentioned research at a 975-year seismic hazard level. Fig. 3 to Fig. 6 respectively show the estimated hazard values for the two hazards of TGD and PGD due to soil liquefaction.

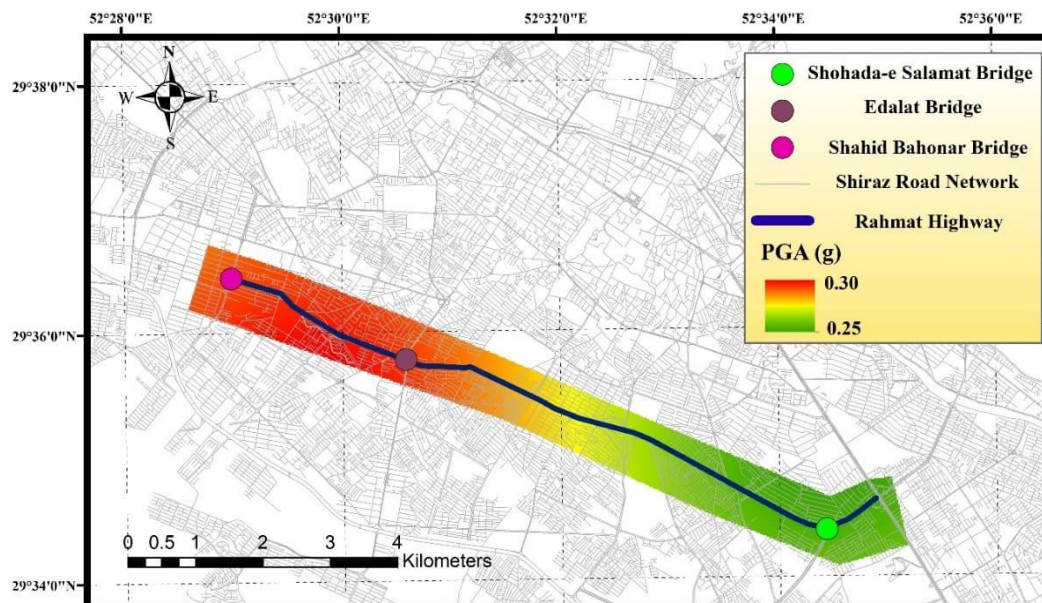


Fig. 3. Distribution of PGA in the case study.

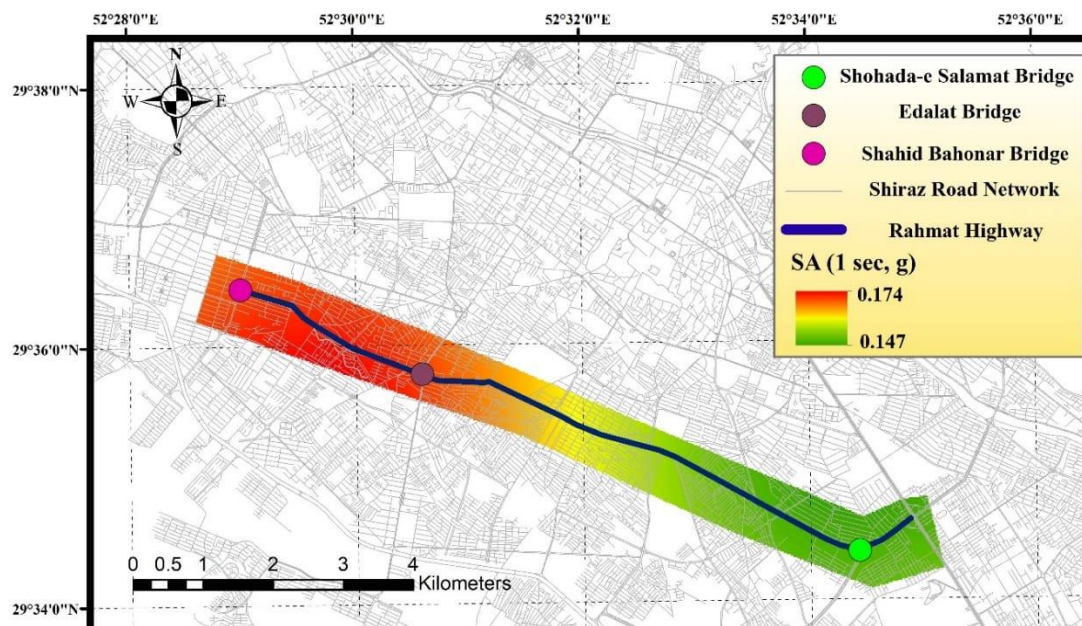


Fig. 4. Distribution of 1-second SA in the case study.

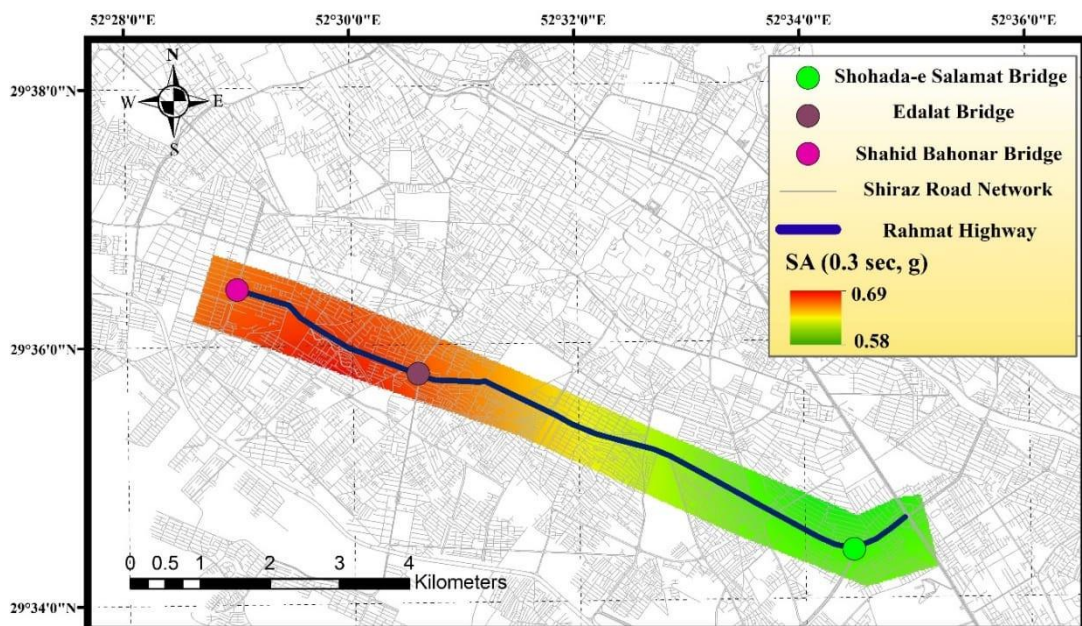


Fig. 5. Distribution of 0.3-second SA in the case study,

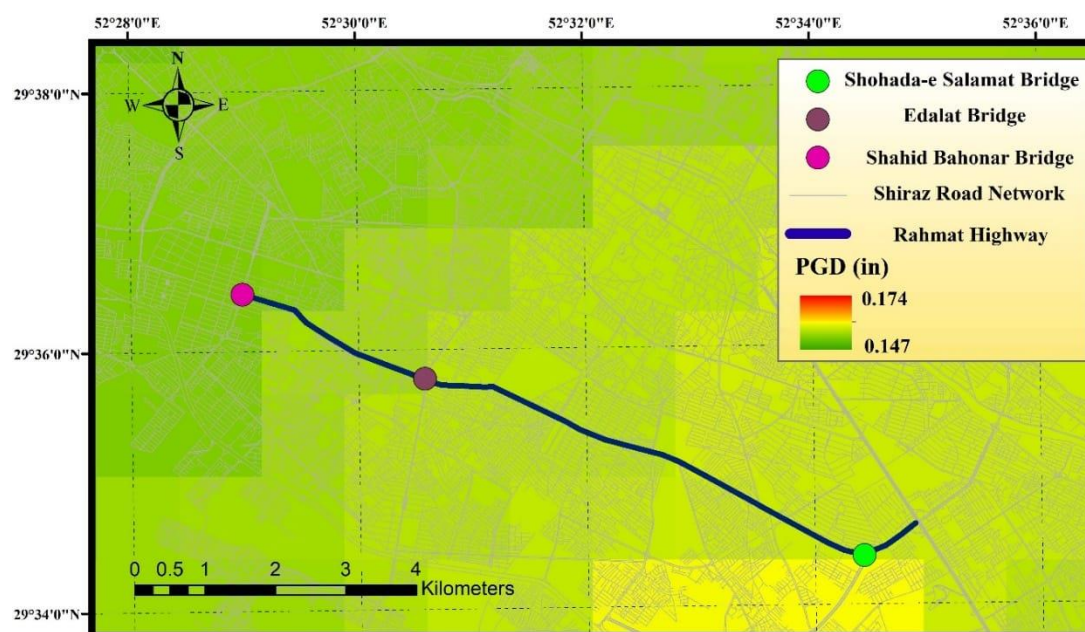


Fig. 6. Distribution of PGD due to soil liquefaction in the case study.

Table 1 presents the estimated hazard parameters at the geographic locations of the bridges, based on Fig. 3 to Fig. 6.

Table 1. Ground movement intensity parameters at the location of bridges.

Bridge Name	PGA (g)	SA1 (g)	SA0.3 (g)	PGD (in)
Shohada-e Salamat	0.345	0.147	0.58	11.4
Edalat	0.393	0.168	0.67	9.1
Shahid Bahonar	0.406	0.176	0.69	6.3

3.2 seismic vulnerability analysis of case study

According to the HAZUS guidelines, the road network consists of three distinct components: roads, bridges, and tunnels. Each component of the road network exhibits different behavior when subjected to earthquake phenomena. The Rahmat highway, along the route specified in Figure 2, consists of a highway and several bridges. The vulnerability of the highway is solely influenced by the hazard of PGD. In contrast, for bridges, both the hazard of TGD and PGD are significant concerns. Consequently, the length of the highway was divided into 500-meter sections to enhance the accuracy of soil type identification and ground motion parameter estimation [20]. The methodology used in this study to estimate seismic vulnerability involves the use of fragility curves. These curves provide the probability of reaching or exceeding each damage state based on various levels of ground motion intensity [21], which differ for each component of the road network.

Table 2 presents the factors influencing the fragility curves for different components of the road network.

Table 2. Values used in the fragility curve.

Components of the Road Network	Parameter Used in the Fragility Curve
Roads and Streets	Use of Permanent Ground Displacement Value
Bridges	Use of Three Values: SA at 0.3 and 1 Second, PGA, and Permanent Ground Displacement

Table 3 and Table 4 provide definitions of vulnerability states for roads and bridges in the urban road network according to the HAZUS methodology.

Table 3. Definition of damage states for roads (in Brief) [13].

Damage state	Symbol	Description
None	DS1	No damage occurrence
Slight	DS2	Minor ground settlement
Moderate	DS3	Moderate ground settlement
Extensive	DS4	Extensive ground settlement

Table 4. Definition of damage states for bridges (in Brief) [13].

Damage state	Symbol	Description
None	DS1	No damage occurrence
Slight	DS2	Cracking and minor spalling at the support
Moderate	DS3	Settlement of support, damage occurrence without displacement
Extensive	DS4	Shear failure and unsafe column structure
Complete	DS5	Any collapse of column and loss of bridge deck

Based on the defined damage states, fragility curves for roads and bridges are estimated in HAZUS guidelines. The proposed fragility curves follow a lognormal distribution. The distribution constant for each damage state is presented in Table 5 and Table 6.

Table 5. Fragility function for permanent ground deformation for roads [13].

Damage state	Mean of PGD (in)	β
DS1	-	-
DS2	6	0.7
DS3	12	0.7
DS4	24	0.7

Table 6. Fragility function for PGD due to soil liquefaction and TGD for bridges [13].

Damage state	Mean of PGD (in)	β	Mean spectral acceleration 1 sec (in g)	β
DS1	-	-	-	-
DS2	3.9	0.2	0.6	0.6
DS3	3.9	0.2	0.9	0.6
DS4	3.9	0.2	1.3	0.6
DS5	13.8	0.2	1.6	0.6

According to Table 5, the fragility curve for roads is presented in Fig. 7.

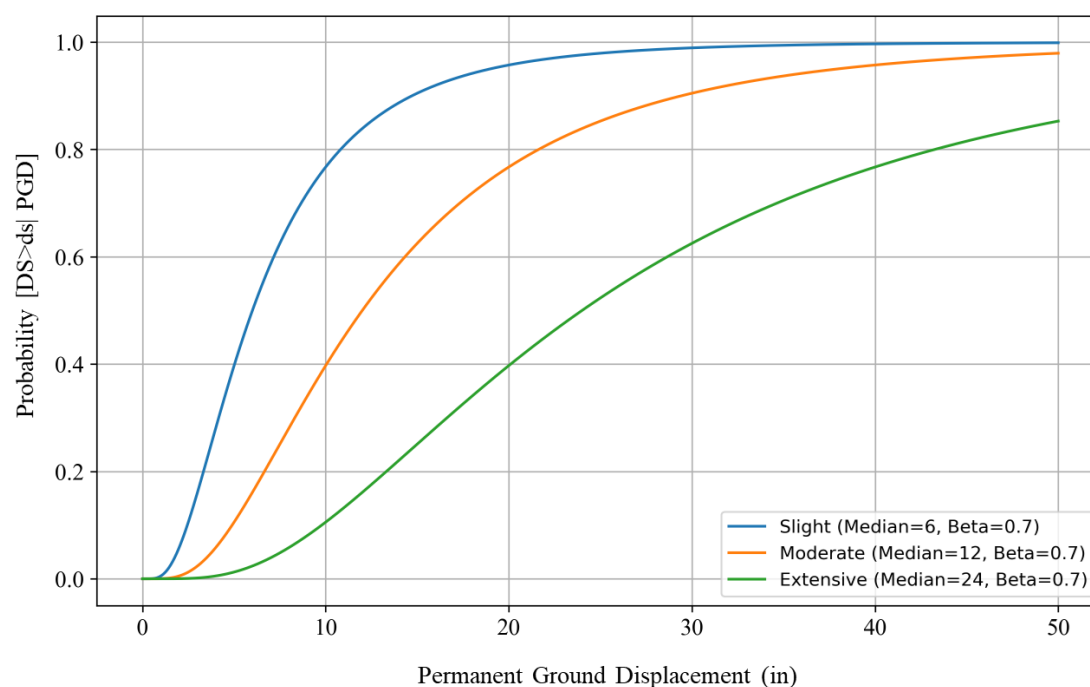


Fig. 7. Fragility curve for roads [13]

The fragility curves for bridges, addressing both the hazard of TGD and PGD due to liquefaction, are depicted in Fig. 8. The dispersion level for each seismic hazard is consistent across all vulnerability states, with differences only in mean values.

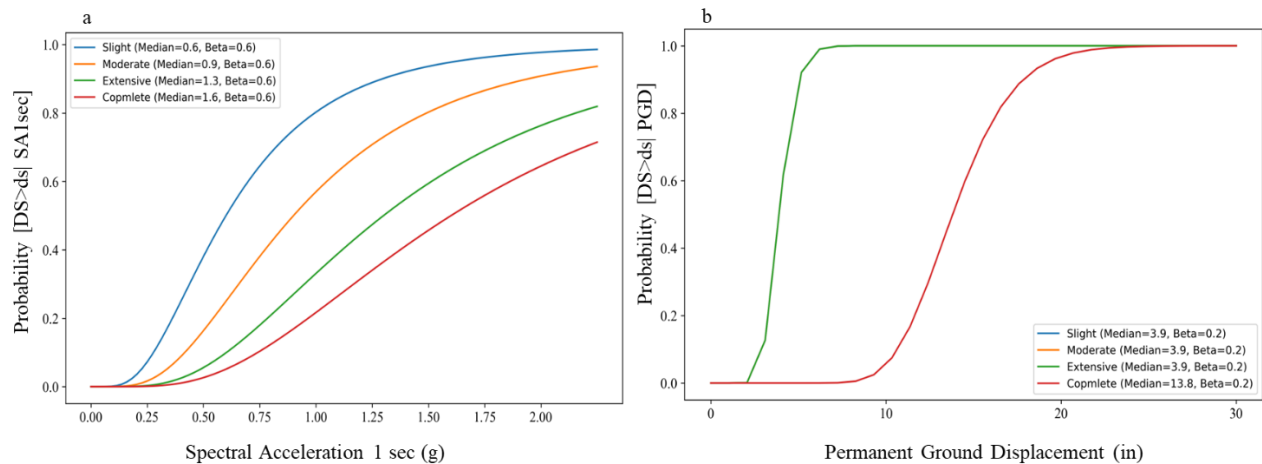


Fig. 8. Fragility curve for bridges, a) due to TGD, b) due to PGD [13]

Considering the equations and figures presented, this step provides the probability of exceeding the defined damage states. For this purpose, the study first addresses the probabilities related to the roads of the network and then those related to the highway bridges in two separate sections. As previously outlined, to achieve higher precision in evaluation, the highway length was divided into 500-meter sections, and the hazard results and probabilities were calculated for each section. Accordingly, Table 7 presents the results related to vulnerability along the highway route.

Table 7. Exceedance probabilities for different road segments.

segments of the highway	$P[ds \geq DS2]$	$P[ds \geq DS3]$	$P[ds \geq DS4]$	$P[ds = DS1]$	$P[ds = DS2]$	$P[ds = DS3]$	$P[ds = DS4]$
1	0.81	0.47	0.14	0.19	0.35	0.33	0.14
2	0.81	0.47	0.14	0.19	0.35	0.33	0.14
3	0.81	0.47	0.14	0.19	0.35	0.33	0.14
4	0.81	0.47	0.14	0.19	0.35	0.33	0.14
5	0.81	0.47	0.14	0.19	0.35	0.33	0.14
6	0.81	0.46	0.14	0.19	0.35	0.33	0.13
7	0.83	0.48	0.15	0.17	0.34	0.33	0.15

8	0.78	0.41	0.12	0.22	0.37	0.30	0.11
9	0.78	0.41	0.12	0.22	0.37	0.30	0.11
10	0.78	0.41	0.12	0.22	0.37	0.30	0.11
11	0.78	0.41	0.12	0.22	0.36	0.30	0.11
12	0.78	0.41	0.12	0.22	0.37	0.30	0.11
13	0.78	0.41	0.12	0.22	0.37	0.30	0.11
14	0.78	0.41	0.12	0.22	0.37	0.30	0.11
15	0.78	0.41	0.12	0.22	0.37	0.30	0.11
16	0.72	0.34	0.08	0.28	0.38	0.26	0.08
17	0.72	0.34	0.08	0.28	0.38	0.26	0.08
18	0.72	0.34	0.08	0.28	0.37	0.26	0.08
19	0.72	0.34	0.08	0.28	0.37	0.26	0.08
20	0.56	0.20	0.04	0.44	0.36	0.17	0.03
21	0.53	0.18	0.03	0.47	0.35	0.16	0.03

In the vulnerability analysis of bridges, certain bridge characteristics, such as length, number of spans, span width, and the alignment of the bridge columns relative to the road, are considered. The mentioned components are used in Equations (11) and (12) [13]:

$$K_{skew} = \sqrt{\sin(90 - \alpha)} \quad (11)$$

$$K_{3D} = 1 + \frac{0.25}{(N - 1)} \quad (12)$$

where K_{skew} is the parameter for adjusting the bridge column angle, K_{3D} is a factor related to the curvature of the bridge deck, and N is the number of bridge spans. It is important to note that in this analysis, only the main deck of the bridge was analyzed, and the effects of the bridge loops were not considered. Therefore, the referenced values are consistent for all cases. Furthermore, using the parameters provided in Equations (11) and (12), the mean value of the fragility function due to TGD according to the HAZUS methodology is presented in Table 8. Table 9 through Table 12 present the probabilities of vulnerability for the bridges studied in this research.

Table 8. Adjusted values of fragility functions based on bridge structures [13].

Damage state	Mean spectral acceleration 1 sec (in g)	β
DS1	-	-
DS2	0.7542	0.6
DS3	1.131	0.6
DS4	1.634	0.6
DS5	2.01	0.6

Table 9. Exceedance probabilities for bridges based on PGD due to soil liquefaction.

Bridge name	$P_{PGD}[ds \geq DS2]$	$P_{PGD}[ds \geq DS3]$	$P_{PGD}[ds \geq DS4]$	$P_{PGD}[ds \geq DS5]$
Shohada-e Salamat	1.0	1.0	1.0	0.16
Edalat	1.0	1.0	1.0	0.017
Shahid Bahonar	1.0	1.0	1.0	0.0

Table 10. Exceedance porobabilities for bridges based on TGD.

Bridge name	$P_{S4I}[ds \geq DS2]$	$P_{S4I}[ds \geq DS3]$	$P_{S4I}[ds \geq DS4]$	$P_{S4I}[ds \geq DS5]$
Shohada-e Salamat	0.003	0.0	0.0	0.0
Edalat	0.006	0.0	0.0	0.0
Shahid Bahonar	0.008	0.0	0.0	0.0

Table 11. Combined exceedance probabilities for bridges.

Bridge name	$P_{comb}[ds \geq DS2]$	$P_{comb}[ds \geq DS3]$	$P_{comb}[ds \geq DS4]$	$P_{comb}[ds \geq DS5]$
Shohada-e Salamat	1.0	1.0	1.0	0.16
Edalat	1.0	1.0	1.0	0.016
Shahid Bahonar	1.0	1.0	1.0	0.0007

Table 12. Combined probability of occurrence for each damage state in bridges.

Bridge name	$P_{comb}[ds = DS2]$	$P_{comb}[ds = DS3]$	$P_{comb}[ds = DS4]$	$P_{comb}[ds = DS5]$
Shohada-e Salamat	0.0	0.0	0.83	0.16
Edalat	0.0	0.0	0.98	0.016
Shahid Bahonar	0.0	0.0	0.99	0.004

3.3 seismic loss analysis of case study

After performing a seismic vulnerability analysis and determining the exceedance probability of various damage states, it is essential to translate the qualitative damage assessments of different network sections into common economic costs. In this regard, the HAZUS guidelines provide a method based on calculating the total damage ratio and using the replacement cost of components. The total damage ratio is calculated by aggregating the damage ratio in each damage state, as outlined in Table 13, and considering the probability of each damage state. The replacement cost is also provided in Table 13.

Table 13. Damage estimation of road network component [22].

Component of Road Network	Damage State	Damage Ratio	Replacement cost
Road	DS2	0.05	3.3 million dollars
	DS3	0.2	per kilometer

Bridge	DS4	0.7	3450 dollars per square meter
	DS2	0.03	
	DS3	0.08	
	DS4	0.25	
	DS5	1.0	

Given these findings, an earthquake with a 975-year return period in Shiraz is estimated to cause approximately 4.7 million in damage along Rahmat highway. The estimated damage per square meter for Shohada-e Salamat, Edalat, and Shahid Bahonar bridges is \$1304, \$924, and \$870, respectively.

8. CONCLUSION

Highways are integral components of modern infrastructure, facilitating the transportation of people, goods, and services. They enhance social connectivity by linking cities, towns, and rural areas, providing easier access to amenities and opportunities. However, earthquakes can have significant adverse impacts on highways. Seismic events can induce structural damages such as cracks and fractures in roads, bridges, and tunnels due to the TGD and PGD. These damages can disrupt transportation networks and lead to costly repairs and economic losses. Ensuring the resilience of highways and identifying critical bottlenecks during earthquakes is essential from various perspectives, including post-earthquake disaster management and the refinement of design codes. This study proposes a methodology for assessing the seismic risk of urban road networks and applies it to a case study in the earthquake-prone city of Shiraz. The findings of this research can provide valuable insights to decision-makers and can also be utilized in rapid earthquake assessment systems.

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Investigating the Potential of Graphene Aerogels in Combating Marine Oil Pollution

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Abstract

Graphene aerogels have emerged as a promising material for environmental remediation, especially in the field of combating marine oil pollution. This paper examines the unique properties of graphene aerogels such as high surface area, hydrophobicity, and excellent adsorption capacity, which make them effective for oil spill cleanup. Traditional oil spill correction evaluates. The findings show that graphene aerogels not only provide superior performance but also offer opportunities for innovative applications in environmental management. This study highlights the efficiency, feasibility, and scalability of graphene aerogels and discusses their environmental impacts and safety considerations. In addition, the article identifies gaps in current research and suggests future directions, including the development of sustainable synthesis methods, functionalization techniques, and comprehensive environmental assessment. Graphene aerogels, with their exceptional properties and versatility, hold significant promise for reducing marine oil pollution and protecting marine ecosystems.

Keywords: Graphene aerogels, Marine oil pollution, Environmental remediation, Oil spill Cleanup.

1. Introduction

1.1. Context of Marine Oil Pollution and its Environmental Impacts

Marine oil pollution is a significant environmental problem that affects oceans and coastal areas around the world. The main sources of oil pollution are: oil spills from tanker accidents, operational discharges of ships, and oil production activities at sea. The environmental impacts of oil spills are deep and multifaceted, affecting marine life, ecosystems, and human activities. Oil spills, large amounts It introduces hydrocarbons into the marine environment, leading to immediate and long-term environmental damage. The physical properties of oil, such as its buoyancy and viscosity, allow it to spread quickly on the surface of the water, creating smudges that can cover large areas. This diffusion capability leads to widespread pollution of marine habitats, affecting a wide range of organisms, from plankton to large mammals and seabirds. Toxic components of petroleum, especially polycyclic aromatic hydrocarbons (PAHs), can cause acute and chronic health effects in marine organisms, including carcinogenicity, mutagenicism, and reproductive disorders. [1] In addition, oil spills can lead to hypoxic conditions, where oxygen levels in the water are significantly reduced due to the microbial decomposition of hydrocarbons. This oxygen depletion can cause widespread deaths of fish and invertebrates, further disrupting the marine food web. Effect of oil suffocation on marine plants such as seagrasses and mangroves, photosynthesis and nutrient exchange and leads to habitat loss of many species. The socio-economic impact of marine oil pollution is also significant. Coastal communities that rely on fishing and tourism are particularly vulnerable. Oil pollution in fishing areas leads to reduced fisheries, loss of income, and food insecurity. Efforts to reduce oil pollution have traditionally included mechanical recovery methods, chemical dispersants, and bioremediation. However, these methods often face limitations in efficiency, cost, and environmental side effects. Mechanical recovery is hampered by rough sea conditions, chemical

dispersants can introduce additional pollutants, and bioremediation is slow, depending on environmental conditions it has [4].

1.2. Introduction of graphene aerogels and their properties

Graphene aerogels are a new class of materials that have gained traction due to their potential applications in environmental remediation, particularly in oil spill cleanup. Graphene, a single layer of carbon atoms arranged in a hexagonal lattice, exhibits exceptional mechanical strength, electrical conductivity, and thermal stability. Graphene, when structured in the form of aerogels, can be very Porous and lightweight, combining the remarkable properties of graphene with a three-dimensional framework [5].

The unique properties of graphene aerogels include:

- **High Surface Area:** Graphene aerogels have a high effective surface area that provides abundant active sites for adsorption. This feature is crucial for capturing large volumes of oil and other hydrophobic contaminants from the water.
- **Hydrophobicity & lipophilicity:** The hydrophobic (water-repellent) and lipophilic (oil-absorbing) nature of graphene aerogels makes them highly selective for oil compared to water. This higher selectivity increases their efficiency in separating oil from water, even in the challenging marine environments.
- **Mechanical Strength and Flexibility:** The strong mechanical properties of graphene aerogels ensure that they retain their structure under a variety of environmental conditions. This durability is essential for practical applications where the material must withstand mechanical stress during establishment and recovery.
- **Reusability:** Graphene aerogels can be reconstructed and reused multiple times with minimal performance loss. This reusability reduces the overall cost and environmental footprint of the remediation process [6].

1.3. Research Objectives and Importance of Studying Graphene Aerogels for Oil Spill Remediation

The main purpose of this study is to investigate the potential of graphene aerogels as an effective material to combat marine oil pollution. This study aimed to:

- Evaluation of Adsorption Capacity and Efficiency of Graphene Aerogels in the Removal of Different Types of Oil from Seawater.
- Comparison of the Performance of Graphene Aerogels with Traditional Oil Spill Remediation Methods.
- Feasibility and Scalability Evaluation of Graphene Aerogels in Large-Scale Oil Spill Response Operations.
- Identification of potential environmental impacts and safety considerations associated with the deployment of graphene aerogels in marine environments.

An important facet of this study lies in addressing the current limitations and risks of oil spill remediation technologies. This research seeks to provide a more efficient, cost-effective, and environmentally friendly solution for oil spill cleanup by leveraging the unique properties of graphene aerogels. The potential benefits of graphene aerogels include higher adsorption capacity, faster cleanup time, and reduced environmental damage compared to existing methods. In addition, this research contributes to the broader field of nanotechnology and environmental engineering by advancing our understanding of how new materials can be applied to real-world environmental challenges. The findings of this study could pave the way for the development of new materials and technologies that enhance our ability to protect marine ecosystems and coastal communities from the destructive effects of oil pollution. [7]

2. Literature Review

2.1. Exploring the Available Methods for Oil Spill Cleanup and Their Limitations

Oil spills have significant environmental and socioeconomic impacts, and require effective cleanup methods. Several traditional and emerging techniques have been employed to remediate oil spills, each with its own set of benefits and limitations.

Mechanical recovery: Mechanical methods such as booms, skimmers, and adsorbents are widely used to recover oil spills. Booms inhibit the spread of oil, while skimmers remove oil from the surface of the water. Adsorbents, materials that absorb or absorb liquids, are also used to collect oil. However, these methods are often inefficient in rough sea conditions and have a limited capacity to handle large volumes of oil. They also require significant manpower and resources to deploy and maintain. [9]

Chemical dispersants: Chemical dispersants are used to break down oil into smaller droplets, increasing microbial decomposition. While dispersants can be effective in reducing the immediate effects of oil spills, they also release additional chemicals into the environment that can be toxic to marine life. In addition, their effectiveness is affected by environmental conditions such as temperature and salinity. [10]

On-site incineration: On-site incineration involves igniting the oil on the surface of the water. This method quickly reduces the volume of oil spilled but produces air pollutants, including soot and volatile organic compounds, which pose health risks to humans and wildlife. [11]

Bioremediation: Bioremediation uses microorganisms to break down oil into less harmful materials. This method is considered environmentally friendly and cost-effective. However, the efficiency of bioremediation depends heavily on environmental factors such as temperature, nutrient availability, and oxygen levels. This process can be slow and may not be suitable for large-scale spills. [12]

Adsorbent-based technologies: Adsorbents are materials that absorb or adsorb oil from water. Recent advances in adsorbents include the development of hydrophobic and fatophilic materials that selectively absorb oil while repelling water. Despite their effectiveness, these materials often face challenges related to reusability, disposal, and cost. [13]

Advanced nanomaterials: Nanomaterials, including carbon nanotubes and magnetic nanoparticles, hold promise for oil spill cleanup due to their high surface area and absorption capacity. These materials can be engineered to increase their hydrophobicity and lipidity, improving their efficiency in oil recovery. However, the large-scale application of nanomaterials is hampered by the high production costs and potential environmental risks associated with the emission of nanomaterials is. [14]

2.2. A Detailed Review of the Properties of Graphene Aerogels for Oil Spill Correction

Graphene aerogels have emerged as a promising material for oil spill cleanup due to their unique properties. Graphene, a single layer of carbon atoms arranged in a hexagonal lattice, exhibits exceptional mechanical strength, electrical conductivity, and thermal stability. When structured in the form of an aerogel, graphene can achieve a highly porous and light shape and remarkable properties. Combine graphene with a three-dimensional framework. [15]

High surface area and porosity: Graphene aerogels have a very high surface area that provides abundant active sites for oil adsorption. The porous structure allows for the placement of large volumes of oil and increases the overall adsorption capacity. [16]

Hydrophobicity & lipophilicity: The hydrophobic (water-repellent) and lipophilic (oil-absorbing) nature of graphene aerogels makes them highly selective for oil than water. This selectivity is achieved through surface functionalization, which can be adjusted to increase the interaction with hydrophobic compounds while minimizing

water absorption. Hydrophobicity and lipidophilia of graphene aerogels Efficient separation It makes it possible to extract oil from water even in challenging marine environments. [17]

Mechanical Strength and Flexibility: Graphene aerogels have excellent mechanical properties and maintain structural integrity under a variety of environmental conditions. This strength is essential for practical applications where the material must withstand mechanical stress during implementation and recovery. The flexibility of graphene aerogels allows them to conform to irregular surfaces and facilitate the collection of oil from various substrates. [18]

Thermal conductivity & photothermal effect: Graphene aerogels exhibit high thermal conductivity, which can be used for advanced oil recovery. The photothermal effect, in which the material converts absorbed light into heat, can be used to reduce the viscosity of heavy oils and make them easier to collect. This feature is especially suitable for cleaning up high-viscosity crude oil spills It is useful that it is challenging to manage using traditional methods. [19]

Reusability and Regeneration: One of the significant advantages of graphene aerogels is their reusability. Once the oil has been absorbed, the aerogels can be regenerated through simple processes such as squeezing or heating, restoring their adsorption capacity. This reusability reduces the overall cost and environmental footprint of the remediation process. Studies have shown that graphene aerogels can perform their own in multiple cycles of absorption and regeneration. [20]

2.3. Previous Studies on the Use of Nanomaterials, Especially Graphene-Based Materials, in Environmental Applications

The use of nanomaterials in environmental remediation has been a growing field of research. Graphene-based materials, in particular, have been extensively studied for their potential in various environmental applications, including oil spill cleanup.

Graphene Oxide and Reduced Graphene Oxide: Graphene oxide (GO) and reduced graphene oxide (rGO) have been investigated for their adsorption capabilities. These materials have a high surface area and adjustable surface chemistry that makes them effective adsorbents for organic pollutants. Studies have shown the use of GO and rGO in the removal of oil from water, with modified graphene materials that have been used due to Increased hydrophobicity and adsorption capacity show higher performance. [21]

Composite Materials: Combining graphene with other materials can further enhance its properties. For example, composite materials made of graphene and magnetic nanoparticles have shown improved oil absorption and easy separation using an external magnetic field. These composites use the high surface area of graphene and the magnetic properties of nanoparticles.

Functionalized graphene: Functionalizing graphene with different chemical groups can adjust its surface properties for specific applications. For example, functionalized graphene with hydrophobic and lipophilic groups has been developed to selectively absorb oil from water. These functionalized graphene materials exhibit high selectivity and capacity to absorb oil, making them suitable for use in leak remediation They make suitable oil. [22]

Aerogels and sponges: Graphene aerogels and sponges have been particularly effective in cleaning up oil spills due to their unique structural properties. These materials combine high porosity, mechanical strength, and surface, providing an efficient platform for oil adsorption. The lightweight nature of aerogels and sponges allows for easy deployment and recovery, making them suitable for large-scale applications. It is a great practice." [23]

Case Studies and Practical Applications: Several case studies have demonstrated the practical application of graphene-based materials in oil spill cleanup. For example, solar-heated reduced graphene oxide (rGO) sponges have been used to rapidly absorb viscous crude oil, and the photothermal effect has been used to reduce oil viscosity and increase adsorption rates. These case studies explore the potential of graphene-based materials to address It highlights real-world environmental challenges. [24]

3. Methodology

3.1. Describing the Research Approach: Library-Based Methodology

The research approach for this study is a library-based methodology (bibliographic) that involves the systematic collection, review and analysis of existing literature related to graphene aerogels and their potential to remediate oil spills. This methodology is suitable for combining existing knowledge, identifying research gaps, and generating new insights without conducting major empirical research. A library-based methodology refers to secondary data sources such as It relies on books, journal articles, conference papers, and other scientific publications. This approach allows researchers to make comparisons across studies based on existing knowledge and provide an overview of the current state of research in a particular field. This is especially useful in areas where extensive empirical studies have already been conducted, providing a rich foundation for analysis and synthesis. [25]

3.2. Criteria for Selecting Texts

To ensure the relevance and quality of the literature reviewed, the following criteria were used to select references:

- **Relevance:** Only texts that were directly related to graphene aerogels, oil spill remediation, and environmental applications of nanomaterials were included. This criterion ensures that the review remains focused and relevant on the research objectives.
- **Novelty:** Due to the rapid advances in nanotechnology and environmental sciences, only publications from the last five years (from 2020 onwards) were considered. This helps to record the latest developments and current trends in the field. [26]
- **Credibility:** Peer-reviewed journal papers, conference papers, and books published by reputable academic publishers were prioritized. These references are likely to undergo rigorous review processes, ensuring the reliability and validity of the findings. [27]
- **Diversity:** A diverse range of resources, including theoretical, empirical, and review articles, are included to provide an overview of the topic. This diversity helps capture different perspectives and methods, enriching the analysis. [28]

3.3. Data Collection and Analysis MethodsData Collection

The data collection process consisted of several steps:

- **Database search:** Academic databases such as Google Scholar, ScienceDirect, PubMed, and Web of Science were used to search for relevant literature. Keywords and phrases related to graphene aerogels, oil spill remediation, nanomaterials, and environmental applications were used to identify relevant studies.
- **Manual screening:** The titles, abstracts and keywords of the identified studies were manually checked to ensure relevance. Studies that did not meet the selection criteria were excluded at this stage.
- **Full-text review:** The full text of the selected studies was reviewed in detail. Key information, including research objectives, methodology, findings, and conclusions, were extracted and recorded.

3.4. Data Analysis

The analysis of the collected data consisted of several steps:

- **Thematic analysis:** Thematic analysis was performed to identify the common themes and patterns in the selected studies. This included coding the extracted information and grouping it into thematic categories such as the properties of graphene aerogels, comparative performance with traditional methods, and potential environmental impacts. [28]
- **Comparative analysis:** The performance of graphene aerogels was compared with traditional methods of oil spill remediation based on criteria such as adsorption capacity, reusability, and environmental impacts. This comparative analysis helped to highlight the advantages and limitations of graphene aerogels in different fields. [29]

- **Synthesis of Findings:** Findings from thematic and comparative analyses were combined to provide an overview of the potential of graphene aerogels to remediate oil spills. This combination included identifying research gaps and proposing future research directions. [30]

The library-based methodology used in this research provides a robust framework for incorporating existing knowledge and generating new insights. By systematically collecting and analyzing the relevant literature, this study aims to provide a comprehensive understanding of the potential of graphene aerogels in the fight against marine oil pollution.

4. Results and Discussion

4.1. Analysis of the Findings of the Reviewed Texts

Graphene aerogels have shown significant potential for oil spill correction due to their unique properties. These materials combine the exceptional properties of graphene with a highly porous and lightweight structure, making them highly effective at absorbing oil and other hydrophobic materials.

4.2. Function and Properties

The reviewed literature consistently emphasizes the high adsorption capacity of graphene aerogels. For example, Jay et al. (2020) reported that Enteromorpha-modified graphene aerogels (EGA) exhibit excellent adsorption capacity compared to petroleum and organic solvents, which perform significantly better than virgin graphene aerogels. This increase is attributed to the introduction of renewable enteromorphs, where the surface area and volume increase as the pores of the material increase and thus improve its absorption capabilities. [16]

Another study by Luo et al. (2020) showed the effectiveness of microsphere aerogels of reduced carbon nanotube/graphene oxide in the cleanup of heavy crude oil spills. These aerogels use the photothermal effect to reduce the viscosity of crude oil, thereby increasing its absorption. The study found that under sunlight, the surface temperature of the aerogel rises rapidly, significantly reducing the viscosity of crude oil and facilitates rapid absorption. [20]

Reusability and Environmental Impact One of the key advantages of graphene aerogels is their reusability. Studies such as Hu et al. (2022) emphasize the remarkable elasticity and mechanical stability of graphene aerogels, which maintain efficiency of more than 90% after multiple adsorption-compression cycles. This feature significantly reduces the environmental impact and costs associated with oil spill remediation because the material can be used repeatedly without significant loss of performance. [13]

4.3. Comparison of Graphene Aerogels with Other Materials

Compared to traditional materials and other advanced nanomaterials, graphene aerogels offer superior performance in several key areas.

Traditional adsorbents: Traditional adsorbents such as polypropylene and activated carbon have been widely used to correct oil spills. However, they often suffer from limitations such as low adsorption capacity, poor reusability, and environmental degradation issues. On the other hand, graphene aerogels exhibit a much higher adsorption capacity. For example, the adsorption capacity of graphene aerogels can reach 310 grams which is significantly higher than traditional adsorbents. [15]

Advanced nanomaterials: Compared to other nanomaterials such as carbon nanotubes and magnetic nanoparticles, graphene aerogels offer a combination of high surface area, excellent mechanical properties, and adjustable surface chemistry. The study by Tucker et al. (2020) found that reduced graphene oxide composite aerogels

– silica exhibit superior performance in terms of oil selectivity and long-term hydrophobicity, making them more durable and effective for oil spill cleanup It does." [31]

4.4. Efficiency, Feasibility and Scalability of Using Graphene Aerogels

Efficiency: The efficiency of graphene aerogels in oil spill correction is highlighted by their high adsorption capacities and fast adsorption rate. For example, Hu et al. (2022) showed that their MOF/graphene aerogel can quickly absorb crude oil and significantly reduce cleanup time compared to traditional methods [13]. The photothermal effect used in some graphene aerogels makes their absorption easier by reducing the viscosity of heavy oils.

Feasibility: The feasibility of using graphene aerogels to clean up oil spills is supported by their mechanical stability and reusability. Studies have shown that these materials can withstand multiple cycles of absorption and regeneration without significant loss of performance. This makes them a cost-effective solution for long-term oil spill management.

Scalability: Scalability continues to be a challenge for the widespread application of graphene aerogels. Processes for producing graphene aerogels, such as hydrothermal and freeze-drying methods, can be complex and costly. However, recent advances in the manufacture of graphene aerogels using more sustainable and cost-effective methods, such as the use of natural and waste materials, offer promising solutions. For example, Huang & colleagues (2022) reported a green, low-cost approach to the synthesis of high-performance graphene-based petroleum adsorbents using bamboo powder and waste paper. [14]

4.5. Potential Environmental Impacts and Safety Considerations

Environmental Impact: The environmental impact of graphene aerogels is generally positive, especially compared to traditional methods of oil spill remediation. The high reusability of graphene aerogels reduces waste and minimizes environmental footprint. In addition, the use of renewable and biodegradable materials in the synthesis of graphene aerogels, as reported by Huang et al. (2022), their environmental friendliness further increases. [14]

Safety considerations: While graphene aerogels exhibit excellent performance in remediating oil spills, it is important to consider the potential safety issues associated with their use. The production and application of nanomaterials can pose risks to human health and the environment if not properly managed. Studies such as Simon-Herrero et al. (2020) have emphasized the importance of assessing the long-term stability and potential toxicity of graphene aerogels to ensure They emphasize their safe use in environmental applications. [27]

5. Innovation & OrientationFutures

5.1. Identifying gaps in current research

Despite significant advances in the use of graphene aerogels to remediate oil spills, several gaps remain in current research.

Scalability and production cost: One of the most significant challenges is the scalability of graphene aerogel production. The synthesis of high-quality graphene aerogels often involves complex and expensive processes such as chemical vapor deposition (CVD) and freeze-drying. These methods are not easily scalable for large-scale industrial applications and limit the widespread use of graphene aerogels in oil spill remediation. [32]

Environmental impact and degradation: The long-term environmental impact of graphene aerogels is not well understood. While graphene-based materials have been promising in the laboratory, their degradation products and potential toxicity in real-world marine environments require further investigation. Studies should look at the life cycle of graphene aerogels, from synthesis to disposal, to ensure their environmental safety. [33]

Durability and Reusability: While graphene aerogels exhibit excellent mechanical properties and reusability, there is still a need to improve their durability under harsh environmental conditions. Long-term exposure to seawater, ultraviolet radiation, and mechanical stress can affect the performance of these materials. Research should focus on increasing the structural integrity and longevity of graphene aerogels to withstand the conditions The real world should be focused. [34]

Functionalization and selectivity: The functionalization of graphene aerogels to increase their selectivity for certain types of oil or contaminants is another area that needs further investigation. The development of multifunctional aerogels that are capable of selectively absorbing oil while disposing of water and other contaminants can significantly improve their efficiency and applicability. [35]

5.2. Proposed Innovative Approaches to Increase the Performance of Graphene Aerogels

To address these gaps and increase the performance of graphene aerogels, several innovative approaches can be proposed:

Green and Sustainable Synthesis Methods: The development of green and sustainable synthesis methods for graphene aerogels can reduce production costs and environmental impact. For example, the use of biomass-derived precursors such as lignin or cellulose can provide a low-cost and renewable source of carbon for the production of graphene aerogels. In addition, the use of environmentally friendly processes such as hydrothermal carbonization or synthesis With the help of microwaves, it can improve the scalability and stability of graphene aerogels. [36]

Hybrid and composite materials: Combining graphene aerogels with other materials can enhance their properties and performance. For example, the synthesis of magnetic nanoparticles in graphene aerogels can facilitate their recovery and reuse using magnetic fields. Similarly, combining graphene with other nanomaterials such as carbon nanotubes or metal-organic frameworks (MOFs) can improve its adsorption capacity, mechanical strength, and photothermal properties to improve the quality of life. [14]

Functionalization of the surface functionalization of the surface of graphene aerogels can adjust their properties for specific applications. Functional groups such as hydroxylic, carboxyl, or amine groups can be introduced to increase the hydrophobicity, lipophilia, or chemical reaction of aerogels. This functionalization can improve the selectivity and efficiency of oil adsorption, making graphene aerogels more versatile and versatile in a variety of environmental conditions. It can be more effective [27]

Photothermal and Photocatalytic Properties: The use of the photothermal and photocatalytic properties of graphene aerogels can further increase their performance. By incorporating materials that can convert light into heat, such as carbon nanotubes or metal nanoparticles, the viscosity of heavy oils can be reduced and their absorption facilitated. In addition, the composition of photocatalytic materials can make possible the degradation of organic pollutants and a substance provide dual purposes for oil spill remediation and water treatment. [24]

5.3. Future Research Directions and Potential Applications in Marine Pollution Control

Future research should focus on the following areas to maximize the potential of graphene aerogels in marine pollution control:

- **Large-scale production and cost reduction:** The development of scalable and cost-effective production methods for graphene aerogels is critical to their practical application. Research should explore alternative synthesis pathways that reduce dependence on expensive precursors and complex processes. For example, the use of agricultural or industrial waste as raw materials can reduce production costs and be a source of sustainability of carbon.
- **Environmental Impact Assessment:** Comprehensive environmental impact assessments are essential to understand the long-term effects of graphene aerogels on marine ecosystems. Studies should examine

degradation products, potential toxicity, and ecological interactions of graphene aerogels under various environmental conditions. This information is essential to develop guidelines and regulations for the safe use and disposal of these materials.

- **Field Trials and Real-World Applications:** Conducting field trials and real-world applications of graphene aerogels provides valuable insights into their performance under practical conditions. These experiments can help identify potential challenges and areas for improvement, such as deployment strategies, recovery methods, and maintenance requirements. Collaborating with industry partners and government agencies can test and implement at scale. Facilitate large graphene aerogels in the control of marine pollution.
- **Integration with other technologies:** Integrating graphene aerogels with other pollution control technologies can increase their overall effectiveness. For example, combining graphene aerogels with mechanical recovery systems, chemical dispersers, or bioremediation techniques can provide a holistic approach to oil spill cleanup. Research should explore synergies between different technologies to develop integrated solutions to control marine pollution .
- **Advanced Characterization and Modeling:** Advanced characterization techniques and modeling approaches can provide a deeper understanding of the properties and behavior of graphene aerogels. Techniques such as electron microscopy, spectroscopy, and computational modeling can shed light on the structural, chemical, and mechanical properties of these materials. This information can guide the design and optimization of graphene aerogels for specific applications.

6. Conclusion

Graphene aerogels show significant potential in combating marine oil pollution due to their unique properties and high efficiency in oil absorption. A comprehensive analysis of the available literature shows that graphene aerogels offer several advantages over traditional oil spill remediation methods, including higher adsorption capacity, superior mechanical properties, and reusability. High surface area and porous structure of graphene aerogels It enables them to absorb large volumes of oil quickly and efficiently. Their hydrophobic and fat-loving nature ensures the selective absorption of oil over water and makes them very effective in marine environments. Despite the challenges associated with their production and scalability, recent advances in synthesis methods, such as the use of biomass-derived precursors and green synthesis techniques, offer promising solutions. The reusability of graphene aerogels further enhances their cost-effectiveness and environmental benefits, as they can be refurbished and reused multiple times without significantly reducing yield. However, the long-term environmental and safety impacts of graphene aerogels remain areas that require further research. While they have a lower environmental footprint compared to traditional materials, comprehensive environmental impact assessments are needed to understand degradation products and their potential toxicity in marine ecosystems. This information is crucial for the development of guidelines and regulations for the safe use and disposal of graphene aerogels. Future research should focus on addressing current gaps, such as increasing the scalability of production methods, improving the durability and selectivity of graphene aerogels, and conducting field tests to evaluate their performance in real-world conditions. In addition, investigating the integration of graphene aerogels with other pollution control technologies can provide comprehensive solutions for oil spill cleanup and environmental protection. In summary, graphene aerogels have significant promise for reducing marine oil pollution due to their exceptional properties, efficiency, and versatility. By addressing current challenges and exploring innovative approaches, graphene aerogels can become a powerful tool in environmental remediation, helping to protect marine ecosystems and reduce the impact of oil spills. The future of graphene aerogels in marine pollution control looks promising, with ongoing research and technological advancements paving the way for their widespread application.

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Safflower, Moringa, and Salicornia Biodiesel: A Comparative Analysis of Sustainable Fuel Alternatives

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ABSTRACT

This article presents a comprehensive study on the feasibility of safflower, moringa, and salicornia as potential feedstocks for biodiesel production. The research investigates the oil extraction process, transesterification reaction, and characterization of the produced biodiesel. Key parameters such as density, viscosity, flash point, acid value, and oxidation stability are determined to assess the fuel quality. The findings demonstrate the potential of these oilseed crops as sustainable sources of biodiesel, offering an environmentally friendly alternative to fossil fuels.

Keywords: Safflower, Moringa, Salicornia, Biodiesel, Transesterification

9. INTRODUCTION

The increasing global demand for renewable energy sources has sparked interest in exploring alternative fuels to reduce reliance on fossil fuels and mitigate environmental impacts. Biodiesel, derived from renewable feedstocks, presents a promising solution. Safflower (such as *Carthamus tinctorius* and *Carthamus tinctorius* L), moringa (such as *Moringa oleifera* and *Moringa peregrina*), and Salicornia (such as *Salicornia persica* and *Salicornia bigelovii*) have gained attention as potential feedstocks due to their oil-rich composition and suitability for cultivation in various regions [1,2,3].

Safflower is known for its high oil content and favorable fatty acid profile, making it a suitable candidate for biodiesel production. Additionally, its cultivation does not compete with food crops, emphasizing its potential as a sustainable feedstock [4]. Moringa, a fast-growing tree with oil-rich seeds, offers the advantage of high oil yields per unit area. Its adaptability to diverse climatic conditions and ability to grow in barren lands make it an attractive option for biodiesel production [5]. Salicornia, a halophyte plant thriving in saline environments, demonstrates potential as a feedstock that does not require freshwater resources for cultivation. Its oil composition and adaptability to marginal lands make salicornia biodiesel a potential sustainable energy source [6].

10. EXPERIMENTAL

1. Oil Extraction:

The oil extraction process was performed using suitable techniques for each plant. Seeds were cleaned, dried, and crushed to obtain safflower and moringa oil. Salicornia oil was extracted from the plant's leaves using a solvent extraction. The extracted oils were then filtered to remove any impurities [1,2,3].

2. Transesterification Process:

Transesterification is the conversion of triglycerides present in the oil into fatty acid methyl esters (biodiesel). The extracted oils were subjected to transesterification using methanol or ethanol and a suitable catalyst, such as sodium

or potassium hydroxide. The reaction was carried out under controlled temperatures of 30 to 80 °C and a stirring rate of 40 to 800 rpm to ensure enough conversion [1,2,3,7].

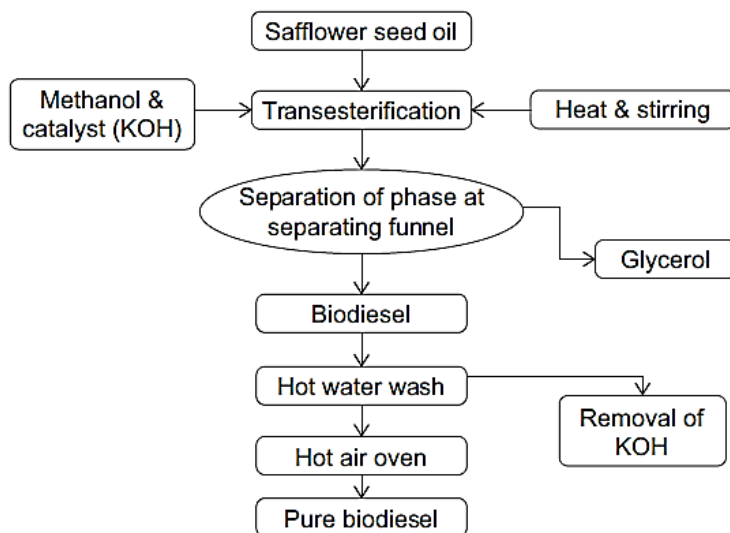


Fig. 1 Schematic diagram of the biodiesel production process by Kumar et al. [4].

3. Biodiesel Properties Analysis:

The produced biodiesel from each feedstock (safflower, moringa, and salicornia) was subjected to various physical and chemical property analyses to evaluate their quality and suitability for use [8,9]:

- Density: The density of each biodiesel sample was determined using a density meter.
- Viscosity: The viscosity of the biodiesel samples was measured using a viscometer.
- Cetane Number: The cetane number, a measure of the fuel's ignition quality, was determined according to standard ASTM methods.
- Flash Point: The flash point, the lowest temperature at which the biodiesel vapor can ignite, was determined using a flash point tester.
- Oxidative Stability: The oxidative stability of the biodiesel samples was assessed by measuring the change in acid value over time through accelerated oxidation tests.
- Acid Value: The acid value, an indicator of the free fatty acid content in the biodiesel, was determined using titration.
- Calorific Value: The calorific value, a measure of the energy content, was determined using a bomb calorimeter.

11. RESULTS AND DISCUSSION

1. Biodiesel Yield:

The highest biodiesel yield from safflower, moringa, and salicornia was determined as 98.4%, 97.79%, and 98.1%, respectively. These yields indicate the feasibility of the three feedstocks for biodiesel production, with safflower and moringa exhibiting relatively higher yields [3,5,10].

2. Biodiesel Properties:

a. Density: Safflower biodiesel showed a density of $874 \pm 9.61 \text{ kg/m}^3$ at 15°C , moringa biodiesel had a density of 0.8767 g/ml , and salicornia biodiesel had a density of $0.9054 \pm 0.001 \text{ mg/ml}$ at 24°C . These varying densities may affect fuel storage and pumping requirements [11,12,13].

b. Viscosity: The viscosities of safflower, moringa, and salicornia biodiesel were measured as 6.45 cSt at 40°C , 12 at 40°C , and 34.74 cSt, respectively. Lower viscosity values indicate better fuel flow properties and potential for various applications [12,14,15].

c. Cetane Number: The cetane numbers for safflower, moringa, and salicornia biodiesel were 52.32 ± 1.15 , 64, and 38.93, respectively. Higher cetane numbers indicate better ignition quality and improved combustion characteristics [11,12,15].

d. Flash Point: The flash points for safflower, moringa, and salicornia biodiesel were 176.00 ± 3.28 , 308, and 198°C , respectively. Higher flash points ensure safer handling and storage [11,12,15].

e. Oxidative Stability: The oxidative stability of safflower biodiesel was superior to moringa and salicornia biodiesel based on the lower increase in acid value over accelerated oxidation tests. Antioxidant additives might be necessary to improve the stability of moringa and salicornia biodiesel [12,13,16].

f. Acid Value: The acid values for safflower, moringa, and salicornia biodiesel were 0.28 ± 0.02 , 0.012, and $1.89 \pm 0.13 \text{ mg KOH/g}$, respectively. Lower acid values indicate a lower free fatty acid content and better fuel quality [11,12,17].

g. Calorific Value: The calorific values of safflower, moringa, and salicornia biodiesel were determined as 41.0, 42, and 5.43 MJ/kg , respectively. Comparable calorific values indicate efficient energy content and potential suitability as a fuel source [12,16,18].

3. Implications and Future Research:

The experimental results indicate the potential of safflower, moringa, and salicornia as biodiesel feedstocks. Each feedstock exhibits specific strengths and limitations in terms of yield and biodiesel properties. Further research should focus on optimizing the production process and addressing the limitations observed, such as improving oxidative stability in moringa and salicornia biodiesel. Additionally, economic and environmental assessments are necessary to determine the viability of large-scale production and the potential impact on sustainable energy production and greenhouse gas emissions [6,13,19].

In this article, many biodiesel are made from safflower, moringa, and salicornia oil, and some helpful information about them is shown in Table 1.

Table 1: Some valuable information about the production of safflower, moringa, and salicornia biodiesel and the results of their processes.

Type	Conditions	Conditions of Maximum Conversion
Safflower oil [1]	Method of conversion: transesterification agitation speed: 40-160 rpm temperature: 50, 60, 70°C solvent: methanol, oil to methanol molar ratio: 1:4, 1:6, 1:8, 1:10 catalyst name: NaOH, catalyst concentration (by wt% of oil): 1, 1.2, 1.4, 1.6, 1.8, 2	Maximum conversion: 96.8 % temperature: 60°C oil to methanol molar ratio: 1:6 catalyst concentration: 2%

Moringa oleifera oil [2]	<p>Method of conversion: transesterification</p> <p>time: 30, 45, 60, 75, 90 min</p> <p>temperature: 30, 40, 50, 60 °C</p> <p>agitation speed: 200, 400, 600, 800 rpm</p> <p>methanol concentration: 10, 20, 30, 40, 50 %</p> <p>catalyst name: KOH, catalyst concentration: 0.5, 0.75, 1.00, 1.25, 1.5 %</p>	<p>Maximum conversion: 82% time: 60 min</p> <p>temperature: 60 °C</p> <p>agitation speed: 400 rpm</p> <p>methanol concentration: 30%</p> <p>catalyst concentration: 1.00%</p>
Salicornia persica oil [3]	<p>Method of conversion: transesterification</p> <p>time: 1.5, 2, 2.5, 3, 3.5 h</p> <p>temperature: 80 °C</p> <p>agitation speed: 350 rpm</p> <p>Solvent: methanol, oil to methanol ratio: 1:6, 1:8, 1:10, 1:12, 1:14</p> <p>Catalyst name: CaO and CaO/Na-ZSM5 (synthetic zeolite), catalyst concentration: 3, 5, 7, 9, 11 %</p>	<p>Maximum conversion: 98.1% time: 3 h</p> <p>oil to methanol ratio: 1:12</p> <p>catalyst name: CaO/Na-ZSM5, catalyst concentration: 9%</p>
Safflower oil [4]	<p>Method of conversion: transesterification</p> <p>time: 60, 75, 90 min</p> <p>temperature: 50, 55, 60 °C</p> <p>agitation speed: 700 rpm</p> <p>solvent: methanol, methanol to oil molar ratio: 4:1, 6:1, 8:1</p> <p>catalyst name: KOH, catalyst concentration (wt%): 0.5, 1, 1.5</p>	<p>Maximum conversion: 95.5%</p> <p>biodiesel viscosity: 7.14 cSt</p> <p>time: 90 min,</p> <p>reaction temperature: 55 °C, methanol to oil: 6:1,</p> <p>catalyst concentration: 1 wt%</p>
Safflower oil [7]	<p>Method of conversion: transesterification</p> <p>time stirring: until the cloudiness persisted</p> <p>solvents: methanol, ethanol</p> <p>catalyst names: KOH, NaOH</p> <p>1:3 oil to methanol & NaOH: 0.825 g (0.0235 mol) & 50 °C "yield :89%"</p> <p>1:3 oil to methanol & KOH: 1.155 g (0.0206 mol) & 25 °C "yield:82%"</p> <p>1:6 oil to ethanol & NaOH :0.4125 g (0.0103 mol) & 25 °C "yield :77.6%"</p> <p>1:6 oil to ethanol & NaOH & 70 °C "yield :85%"</p> <p>1:8 oil to ethanol & KOH :1.155 g (0.0206 mol) & 50 °C "yield :60.3%"</p>	<p>Maximum conversion: 89%</p> <p>solvent: methanol</p> <p>catalyst name: NaOH</p> <p>1:3 oil to methanol & NaOH: 0.825 g (0.0235 mol) & 50 °C</p>
Safflower oil (Carthamus tinctorius L) [11]	<p>Method of conversion: transesterification</p> <p>time: 120 min</p> <p>temperature: 30, 45, 60 °C</p> <p>agitation speed: 180, 360, 600 rpm</p>	<p>Maximum conversion: 98 % temperature: 60 °C</p> <p>agitation speed: 600 rpm</p> <p>oil to methanol molar ratio: 1:6</p>

	solvent: methanol, oil to methanol molar ratio: 1:3, 1:6, 1:9, 1:12, 1:15, and 1:18 catalyst names: KOH, NaOH, KOCH ₃ , NaOCH ₃ catalyst concentration (wt%): 0.25, 0.50, 0.75, 1.00, 1.25, and 1.50%	catalyst name: NaOCH ₃ , catalyst concentration: 1.00%
Safflower oil (Carthamus oxyacantha Bieb.) [14]	Method of conversion: transesterification time: 0.5, 1, 1.5, 2, 2.5 h temperature: 50, 55, 60, 65, 70 °C solvent: methanol, methanol to oil: 3:1, 4:1, 5:1, 6:1, 9:1 catalyst name: NaOH, catalyst concentration (wt%): 0.2, 0.4, 0.6, 0.8, 1%	Maximum conversion: 84% time: 2 h temperature: 65 °C methanol to oil: 5:1 catalyst concentration: 0.6%
Moringa oleifera oil [19]	Method of conversion: transesterification time: 1-10 h reaction temperature: 30-60 °C molar ratios of (medium chain fatty acids: long chain triglycerides: 4:1 catalyst name: lipases as Novozym 435 and Lipozyme RM pressure: 80-120 bar	Maximum conversion: 63.2% time: 5 h reaction temperature: 50 °C molar ratios of (medium chain fatty acids: long chain triglycerides: 4:1 catalyst name: Novozym 435, pressure: 100 bar
Salicornia bigelovii [20]	Method of conversion: pyrolysis Nitrogen inlet temperature: 150 °C Maximum reactor temperature: 550 °C Biomass feed rate: 368 g h ⁻¹ (seed), 186 g h ⁻¹ (seedless-plant) Total nitrogen feed rate: 0.75 lit min ⁻¹ Reactor screw rotation speed: 90 rpm Gas and solid residence time: 1.2 and 13.5 s, respectively	Maximum conversion: about 80%
Moringa oleifera oil [21]	Method of conversion: transesterification time: 4 h temperature: 60 °C stirring rate: 350 rpm solvent: methanol, methanol to oil: 12:1 catalyst name: Zinc Oxide modified with fly ash, catalyst concentration (wt%): 3%	Maximum conversion: about 60%

12. CONCLUSIONS

This study highlights the potential of safflower, moringa, and salicornia as viable feedstocks for biodiesel production. The investigation successfully extracted oil from these crops and carried out the transesterification process to convert the oil into biodiesel. The resulting biodiesel samples exhibited favorable characteristics in density, viscosity, flash point, acid value, and oxidation stability, indicating their potential as renewable fuel sources.

Cultivating safflower, moringa, and salicornia as oilseed crops for biodiesel production offers several advantages. These crops do not compete with food crops, thereby minimizing the ethical concerns associated with biofuel production. Moreover, their ability to thrive in diverse climatic conditions and marginal lands makes them suitable for cultivation in various geographical regions.

The findings of this study contribute valuable insights into the renewable energy sector by identifying safflower, moringa, and salicornia as potential feedstocks for biodiesel production. Further research is warranted to investigate the agronomic practices, sustainability, and economic viability of large-scale cultivation of these crops. Additionally, assessing the environmental impact and life cycle analysis of safflower, moringa, and salicornia biodiesel production would provide a comprehensive understanding of their potential as sustainable alternatives to fossil fuels.

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Exploring the Potential of Biosorption By Algae: A Sustainable Solution for Water Treatment

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ABSTRACT

Biosorption, a promising technique in environmental biotechnology, offers a sustainable strategy for removing pollutants from various wastewater streams. Algae, as a natural and abundant resource, have gained significant attention as biosorbents due to their unique characteristics and efficient pollutant-binding capabilities. This article provides a comprehensive overview of the application of algae in biosorption processes, focusing on their potential in water treatment.

Keywords: Biosorption, Pollutant, Removal, Algae

13. INTRODUCTION

Algae, a diverse and ubiquitous group of photosynthetic organisms, have captured the attention of researchers worldwide due to their remarkable ability to remove contaminants from various environments efficiently. This natural process, known as biosorption, relies on the unique properties of algae to bind and sequester pollutants, providing a sustainable and eco-friendly solution for environmental remediation. This article delves into the fascinating world of biosorption, shedding light on the versatility and efficacy of algae as biosorbents [1].

At its core, biosorption involves the passive uptake of pollutants by living or non-living biomass, wherein the algae's cell walls or extracellular polymeric substances act as the primary binding sites. These natural sorbent materials possess a range of functional groups, including carboxyl, hydroxyl, amino, and sulfhydryl groups, that can readily interact with diverse contaminants, such as heavy metals, organic dyes, and pharmaceuticals [2,3].

One of the essential advantages of utilizing algae for biosorption is their natural abundance, making them an easily accessible and cost-effective resource [4]. Moreover, algae exhibit high growth rates and can be cultured in marine and freshwater environments, making them highly adaptable for large-scale applications. Their inherent ability to proliferate in nutrient-rich wastewater streams offers the dual benefit of treating effluents while harvesting valuable biomass for further utilization [5]. By harnessing the natural affinity of algae for pollutants, the need for expensive and energy-intensive treatment methods can be reduced, thus paving the way for more environmentally friendly approaches to pollution control [4].

As we embark on this exploration of biosorption by algae, it becomes evident that their potential as biosorbents extends beyond environmental remediation. Recent research has also highlighted their role in wastewater treatment, bioremediation of contaminated soils, and even recovering valuable metals from industrial waste streams [6].

By unraveling the intricate interactions between algae and contaminants, scientists and engineers strive to unlock the full potential of these remarkable organisms, revolutionizing the landscape of pollution control and resource recovery. Through a multidisciplinary approach encompassing biology, chemistry, and engineering, we stand at the precipice of a new era where algae-based biosorption technologies promise a cleaner and more sustainable future [7].

Experimental

The present article sets out to provide a highly detailed account of the material and methods employed in the investigation of biosorption by algae. To ensure the reliability and accuracy of our data, we selected algal strains known for their ability to uptake heavy metals or organic pollutants.

1. Selection of Algal Strains: Several algal strains were chosen based on their known ability to uptake heavy metals or organic pollutants [8].
2. Algal Culture Preparation: Algal cultures were prepared according to established protocols. Briefly, the selected algal strains were cultured in appropriate growth media under controlled laboratory conditions, including temperature, light intensity, and photoperiod [9].
3. Biosorption Experiments: Biosorption experiments were conducted using batch studies. Initially, a stock solution of the target pollutant was prepared by dissolving the required amount of pollutant (e.g., heavy metal ions or organic compounds) in deionized water [10].
4. Determination of Optimum pH: To determine the optimum pH for biosorption, a series of experiments were performed by adjusting the initial pH of the pollutant solution using acid or base solutions. The effect of pH on biosorption capacity was evaluated by measuring the adsorption efficiency at different pH levels [11].
5. Adsorption Kinetics Studies: Adsorption kinetics experiments were conducted to understand the rate at which biosorption occurs. A fixed amount of algae biomass was added to the pollutant solution, and samples were collected at regular intervals to measure the remaining concentration of the pollutant. The obtained data were fitted into kinetic models such as pseudo-first-order or pseudo-second-order equations [2].
6. Isotherm Studies: Isotherm studies were performed to determine the equilibrium relationship between the pollutant concentration in the solution and the amount of pollutant adsorbed by the algae. Different isotherm models, such as Langmuir and Freundlich, were used to analyze the experimental data and calculate important parameters like maximum adsorption capacity and intensity [2].
7. Effect of Initial Pollutant Concentration: To study the effect of initial pollutant concentration on biosorption, varying concentrations of the pollutant solution were prepared, ranging from low to high concentrations. The amount of pollutant adsorbed by the algae was determined and plotted against the initial concentration [12].
8. Characterization of Biosorbent: After biosorption experiments, the algae biomass was collected, washed, dried, and characterized using techniques such as scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) [13]. These analyses provided information about the algae biomass's surface morphology and elemental composition before and after biosorption. Biosorption of Pb(II) and Cu(II) on to red algae is shown in Figure 1.

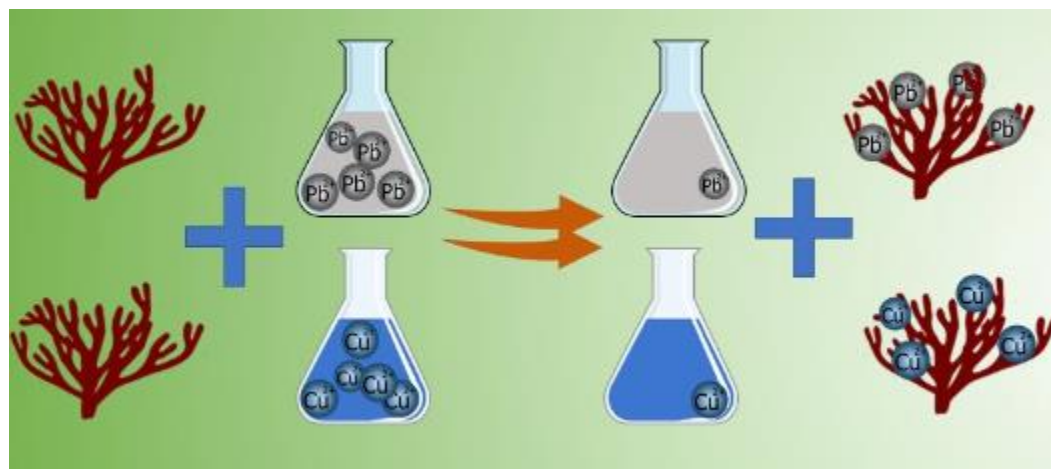


Figure.1. Biosorption of Pb(II) and Cu(II) on to red algae [14].

Results and discussion

Biosorption, a process where living organisms remove and accumulate pollutants from their surroundings, has gained significant attention as an eco-friendly solution for pollution remediation. Algae, a diverse group of photosynthetic microorganisms abundant in aquatic ecosystems, have emerged as promising candidates for biosorption due to their unique properties [15]. This article explores the potential of algae-based biosorption and its applications in addressing various environmental challenges.

Algae's High Efficiency in Biosorption

Algae possess a high surface area-to-volume ratio and a rich cellular composition, making them efficient biosorbents [16]. The presence of functional groups, such as carboxyl, amino, and sulfate groups, on their cell walls enables strong binding and adsorption of pollutants [17]. Studies have reported remarkable biosorption capacities of algae towards heavy metals and organic compounds [7]. These inherent characteristics highlight the immense potential of algae as effective biosorbents.

Mechanisms of Biosorption by Algae

The biosorption process involves various mechanisms, including physical adsorption, chemisorption, ion exchange, and complexation. In physical adsorption, pollutants are attracted to algae surfaces through weak van der Waals forces or electrostatic interactions. Chemisorption occurs when pollutants form covalent bonds with functional groups present on algae cell walls [7,18]. Ion exchange involves the replacement of metal ions bound to algae surfaces with other ions present in the surrounding environment. Complexation refers to the formation of complexes between pollutants and specific binding sites on algae [18]. Understanding these mechanisms is crucial for optimizing and enhancing the efficiency of algae-based biosorption systems.

Applications of Algae-Based Biosorption

The versatility of algae makes them ideal for addressing various pollution challenges across different sectors. Algae can effectively remove heavy metals, nutrients, pharmaceuticals, and organic pollutants in wastewater treatment. Moreover, algae-based biosorbents have been explored for the remediation of contaminated soils and sediments [19]. The potential of algae in radioactive waste management has also been investigated, with promising results in accumulating radionuclides [20]. Additionally, algae-based biosorption shows potential in capturing carbon dioxide from industrial emissions, offering a sustainable approach to mitigating climate change [21]. In this article, a number of algae and some helpful information about them are shown in Table 1.

Table 1: Biosorption efficiency and capacity of some biosorbents and their conditions, including optimum amounts (opt.)

Biosorbent	Removed contaminants	Biosorption efficiency (%)	Biosorption capacity (mg/g)	Biosorption conditions
Sargassum bevanom [9]	Hg (II)	90.24	35.59	pH:1-10 (opt.:7), algae dosage: 0.4 g in 100 mL, temperature: 20–50 °C (opt.:20 °C), equilibrium time: 90 min
Chlorella vulgaris [10]	Hg (II)	-	42.1	temperature: 20, 30, 40 °C (opt.:40 °C), algae dosage: 0.5- 2 g (not significant), equilibrium time: 90 min
Ulva lactuca Linnaeus [11]	Hg (II)	-	27.25 (at pH 3.5), 84.74 (at pH 5.5), 149.3 (at pH 7.0)	pH: 3.5, 5.5, 7 (opt.: 7.0), equilibrium time: 2 h, temperature =25 °C
Chlamydomons reinhardtii [23]	Hg (II), Cd (II), Pb (II)	-	72.2±0.67 (for Hg), 42.6±54 (for Cd), 96.3±0.86 (for Pb)	pH: 2.0-7.0 (opt.:6.0 for Hg and Cd, 5.0 for Pb), temperature: 5–35 °C (not significant), equilibrium time: 60 min
Sargassum fusiforme [24]	Hg (II), Cu (II)	for Hg:70 (at pH 8), 72 (at pH 10), for Cu 90 (at pH 8), 92(at pH 10)	30.86 (for Hg), 7.69 (for Cu)	pH: 8, 10, equilibrium time: 60 min, temperature:25 °C
porphyridium cruentum [25]	Hg (II)	44.8-59.6	2.62	algae dosage: 0.01–1 g/L (opt.:0.25g) , pH:7-10 (opt.:7), contact time: 120 min, temperature: 25, 35, 45 °C (opt.:25 °C)
Cystoseira baccata [26]	Hg (II)	83	178 (at pH 4.5), 329 (at pH 6.0)	biomass concentration: 2.5 g/ L, pH: 0.7-9.0, temperature: 25 °C

Advantages and Challenges

One significant advantage of algae-based biosorption is its cost-effectiveness compared to conventional methods such as chemical precipitation or membrane filtration [4]. Algae can be readily obtained from natural sources or cultivated in controlled environments, reducing production costs [4,7]. Algae biomass generated during the biosorption process can be utilized for applications like biofuel production or fertilizer development, creating a circular economy [22].

However, several challenges need to be addressed to maximize the practical application of algae-based biosorption. These include optimizing biosorption efficiency, scaling up production, ensuring adequate system stability, and

addressing potential ecological impacts [4,22,23]. Research efforts should focus on developing effective immobilization techniques, enhancing selectivity towards specific pollutants, and optimizing operational conditions to overcome these challenges.

Conclusions

Algae-based biosorption offers a promising and sustainable solution for pollution remediation. The unique properties and widespread availability of algae make them excellent biosorbents for various pollutants. By further exploring the mechanisms, optimizing processes, and overcoming existing challenges, algae-based biosorption systems can be harnessed to tackle environmental pollution effectively.

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Mercury Removal by Biochar and Activated Carbon: An Effective Approach for Environmental Remediation

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ABSTRACT

Mercury (Hg) contamination is a pressing environmental issue due to its persistence, bioaccumulation, and toxicity. In recent years, biochar and activated carbon have emerged as effective adsorbents for mercury removal. This article provides an overview of the use of biochar and activated carbon in mercury remediation and highlights their adsorption mechanisms. The potential of various biochar and activated carbon materials, including modified versions, for mercury removal from water, soil, and air is discussed. The regeneration and reusability of these adsorbents are also explored. The findings suggest that biochar and activated carbon offer a sustainable and efficient approach to addressing mercury contamination.

Keywords: Mercury, Adsorption, Biochar, Activated carbon

1. INTRODUCTION

Mercury contamination in the environment poses a significant threat to human health and ecosystems due to its persistence, bioaccumulation, and toxicity. Industrial processes, such as coal combustion, mining, and waste incineration, are major contributors to the release of mercury into the environment. Efforts to mitigate mercury pollution have led to the development of various remediation techniques, among which the use of biochar and activated carbon has shown promising potential [1].

Biochar is a carbon-rich material produced through the pyrolysis of biomass, while activated carbon refers to highly porous carbon materials with a large surface area. Both biochar and activated carbon have attracted considerable attention for their ability to adsorb and remove various pollutants, including heavy metals, from contaminated media. In recent years, their effectiveness in mercury removal has been extensively studied, leading to promising results [2].

The adsorption mechanisms of biochar and activated carbon for mercury removal are primarily attributed to their physical and chemical properties. The high surface area and porosity of these materials provide ample adsorption sites, allowing for efficient binding of mercury ions. Additionally, the presence of functional groups on the surface of biochar and activated carbon, such as oxygen-containing groups, enhances their affinity for mercury species through chemical interactions [3].

Several studies have reported the successful application of biochar and activated carbon for mercury removal in different environmental matrices, including water, soil, and air. For instance, research has demonstrated the effectiveness of biochar derived from various feedstocks, such as agricultural residues, wood waste, and sewage sludge, in reducing mercury concentrations in contaminated water bodies. Similarly, activated carbon-based adsorbents, including activated carbon fibers and granular activated carbon, have shown remarkable performance in mercury removal from both aqueous and gaseous environments [4].

The efficiency of biochar and activated carbon in mercury removal can be further enhanced through modifications and optimization of their properties. Surface modification techniques, such as chemical activation, impregnation of

specific functional groups, and incorporation of metal nanoparticles, have been explored to improve the adsorption capacity and selectivity of these materials towards mercury species [5,6].

Experimental

1. Preparation of Biochar and Activated Carbon Adsorbents:

- **Biochar:** Biochar was prepared through the pyrolysis of various biomass feedstocks, such as agricultural residues, wood waste, or sewage sludge. The feedstock was heated under controlled conditions (e.g., temperature, residence time, and heating rate) in a pyrolysis reactor to produce biochar. The resulting biochar was then milled and sieved to obtain the desired particle size range [7].

- **Activated Carbon:** Activated carbon adsorbents were commercially obtained or synthesized in the laboratory using methods such as carbonization and activation. The carbonization process involved heating the precursor material, such as coconut shells or coal, at high temperatures in an inert atmosphere. Activation was achieved by treating the carbonized material with chemical agents, such as potassium hydroxide or phosphoric acid, followed by thermal treatment [7].

2. Characterization of Adsorbents:

- **Surface Area and Porosity:** The surface area and porosity of the biochar and activated carbon adsorbents were determined using techniques such as Brunauer-Emmett-Teller (BET) analysis and pore size distribution analysis (e.g., Barrett-Joyner-Halenda method) [7].

- **Functional Groups:** The presence of functional groups on the adsorbent surfaces was examined using Fourier-transform infrared spectroscopy (FTIR) or X-ray photoelectron spectroscopy (XPS) [7].

- **Morphology:** The morphology and surface structure of the adsorbents were analyzed using scanning electron microscopy (SEM) or transmission electron microscopy (TEM) [7].

3. Batch Adsorption Experiments:

- **Adsorbate Solution Preparation:** A stock solution of mercury was prepared by dissolving a known amount of mercury compound (e.g., HgCl_2 or $\text{Hg}(\text{NO}_3)_2$) in deionized water. The pH of the solution was adjusted to a desired value using acid or base solutions [8,9].

- **Adsorption Kinetics:** To study the adsorption kinetics, a series of batch experiments were conducted by adding a fixed amount of adsorbent to a known volume of Hg solution. The mixture was agitated at a constant speed using a shaker or magnetic stirrer. Samples were collected at regular intervals, and the concentration of Hg in the solution was measured using techniques such as atomic absorption spectroscopy (AAS) or inductively coupled plasma mass spectrometry (ICP-MS) [10].

- **Adsorption Isotherms:** Adsorption isotherms were determined by varying the initial concentration of Hg in the solution while keeping other parameters constant. The equilibrium concentration of Hg in the solution was measured, and the amount of Hg adsorbed onto the adsorbent was calculated [8,10].

- **Thermodynamic Studies:** Thermodynamic parameters, such as changes in enthalpy (ΔH), entropy (ΔS), and Gibbs free energy (ΔG), were calculated to evaluate the spontaneity and feasibility of the adsorption process [11]. Adsorption of mercury is shown in Figure 1.

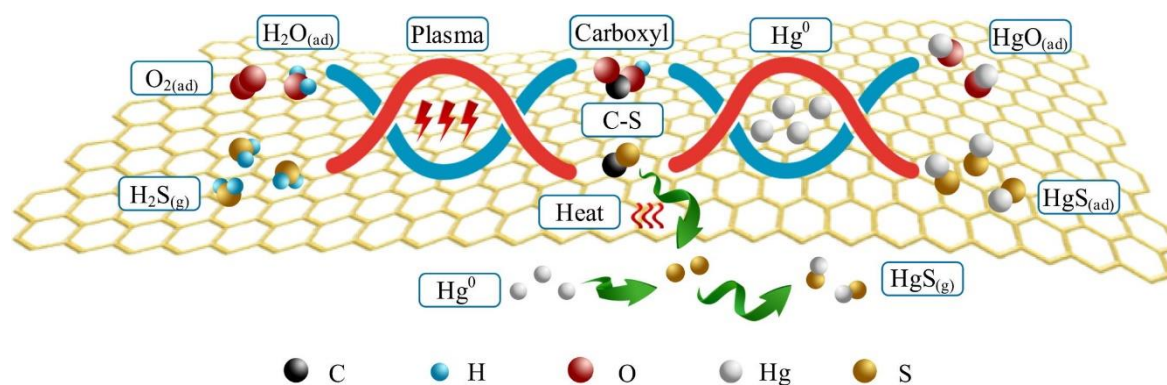


Figure 1. Adsorption of mercury

Results and discussion

The removal of mercury (Hg) from contaminated environments is a critical environmental challenge. Biochar and activated carbon have emerged as promising adsorbents for mercury remediation due to their high surface area, porosity, and affinity for heavy metal ions. This discussion aims to further explore the effectiveness of biochar and activated carbon in mercury removal, considering their adsorption mechanisms, performance in different environmental matrices, potential modifications, and the regeneration and reusability of these materials [8,11,12].

The adsorption mechanisms of biochar and active carbon for mercury removal are primarily attributed to physical and chemical processes. The high surface area and porosity of these materials provide numerous adsorption sites, allowing for efficient binding of mercury species. Additionally, the presence of functional groups on the surface of biochar and active carbon, such as oxygen-containing groups, enhances their affinity for mercury ions through chemical interactions [13,14].

Several studies have demonstrated the effectiveness of biochar and active carbon in mercury removal from various environmental matrices. In the case of water, biochar derived from different feedstocks, including agricultural residues, wood waste, and sewage sludge, has shown remarkable potential in reducing mercury concentrations. For instance, Chen et al. (2014) compared the mercury removal efficiency of biochar and activated carbon derived from sewage sludge and found that both materials exhibited high adsorption capacities [15]. Similarly, activated carbon-based adsorbents, such as activated carbon fibers and granular activated carbon, have shown promising results in mercury removal from aqueous and gaseous environments [16]. In this article, several adsorbents and some helpful information about them are shown in Table 1.

Table 1: Adsorption efficiency and capacity of some adsorbents and their conditions, including optimum amounts (opt.)

Source of adsorbent	Adsorption efficiency	Mercury concentration	Adsorption capacity	Conditions
Licorice residue and Pistachio-nut shell [8]	74.11(Mix-H ₃ PO ₄) and 89.98(M	100 ppm	—	pH: 8.5–9, agitation rate: 300 rpm until equilibrium at room temperature activation temperature: 450, 600, 700 °C (opt.: 600 °C for Mix- ZnCl ₂ , 700 °C for Mix-H ₃ PO ₄), reaction time: 1, 2, 3 h (opt.: 1

	ix- ZnCl ₂) %			for Mix- ZnCl ₂ , 2 for Mix-H ₃ PO ₄), Heating rate: 2.5, 5 °C/min (opt.: 2.5 °C/min), Impregnation ratio: 0.5, 1, 2 g/g (opt.: 1 for Mix-H ₃ PO ₄ , 2 for Mix- ZnCl ₂)
Bagasse pith [9]	—	50 (from synthetic industry wastewater) and 20 (chloralkali industry wastewater) mg/l	172.4 to 188.7 mg/g at 30 °C to 208.3 to 227.3 mg/g at 60 °C	pH range: 4–9 for sulfurized activated carbons and 6–8 for sulfur-free carbon, temperature: 30–60 °C, agitation time: 200 min for sulfurized activated carbons and 240 min for sulfur-free activated carbons
pistachio wood wastes [12]	—	25 mg/l	202 mg/g	pH: 2-10 (opt.: 7.0), adsorption temperature: 25 °C, pyrolysis temperature: 800 °C, pyrolysis time: 0.5-3 h (opt.: 2 h), impregnation ratio: 0-10% (opt.: 5%)
bicarbonate-treated peanut hulls [18]	—	10-20 mg/dm ³	109.89 mg/g	time: 5-180 min (equilibrium time: 90 min), adsorbent dosage: 5-120 mg 100 ml ⁻¹ (opt.: 20 mg 100 ml ⁻¹), pH: 1.5-10.0 (opt.: 4)
olive stones [19]	72%	20 mg/l	20 mg/l	temperature: 400, 550, 700, 850 °C (opt.: 400 °C), pH: 2
sugarcane bagasse [20]	98%	76 mg/l	35.71 mg/g	pH: 1.8-4.0 (opt.: 4), biomass dosage: 5 g/L, temperature: 30, 40, 50 °C (opt.: 30 °C)
antibiotic waste [21]	—	10–40 mg/l	129 mg/g	pH: 2-9 (opt.: 5.5), temperature: 600-950 °C (opt: 950 °C), time: 1-15 min (opt.: 5 min)
Aegina Pistachio Shells [22]	—	60 mg/l	40- 62 mg/g.	pH: 6, agitation rate: 200 rpm for 3 h at room temperature, activation was carried out by impregnation with ZnCl ₂ and heating at 750 °C under N ₂ atmosphere

The performance of biochar and activated carbon in mercury removal can be further enhanced through modifications. Surface modification techniques, such as chemical activation, impregnation of specific functional groups, and incorporation of metal nanoparticles, have been explored to improve the adsorption capacity and selectivity of these materials towards mercury species. For example, Sajjadi et al. (2018) investigated the influence of surface properties and solution chemistry on the mercury removal efficiency of biochar and activated carbon. They found that modifications, such as increasing the surface oxygen content, significantly enhanced the adsorption capacity of these materials [12].

Furthermore, the regeneration and reusability of biochar and activated carbon adsorbents are crucial for their long-term effectiveness in mercury removal and for reducing the overall cost and environmental impact of the remediation process. Various techniques have been investigated for the regeneration of these materials. Thermal regeneration,

solvent extraction, and desorption using specific chemical agents have shown promise in restoring the adsorption capacity of biochar and activated carbon [17].

Despite the promising results, some challenges and knowledge gaps remain. Optimization of the performance of biochar and activated carbon in different environmental conditions, as well as the assessment of their long-term effects, are areas that require further research. Additionally, the scalability and cost-effectiveness of large-scale applications of biochar and activated carbon for mercury removal need to be considered.

Conclusions

The use of biochar and activated carbon for mercury removal offers a sustainable and efficient approach to address the growing concern of mercury contamination in various environmental matrices. Their high adsorption capacity, coupled with the potential for modification and regeneration, makes these materials valuable tools for environmental remediation efforts. However, further research is needed to optimize their performance, evaluate their long-term effects, and explore their applicability under different environmental conditions. By harnessing the potential of biochar and activated carbon, we can take significant strides toward mitigating mercury pollution and safeguarding our ecosystems and human health.

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Visualizing The Strategic Plan of an Organization to Monitor KPIs Using a Dashboard Development Approach. Case Study: Computer Science Faculty of Allameh Tabataba'i University

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Abstract

This research aimed to identify key performance indicators (KPIs) and enhance the monitoring and decision-making processes within the Faculty of Statistics, Mathematics, and Computer Science at Allameh Tabataba'i University. The study explored the feasibility of visualizing these KPIs through the development of interactive strategic dashboards. Initially, by analyzing the faculty's strategic documents, 11 key performance indicators were identified, including scholarly publications, scientific events, and research projects, which were validated based on the SMART model. Subsequently, interactive dashboards were developed using the powerful Microsoft PowerBI software. These dashboards visually represent the status of each key indicator and enable in-depth data analysis. Dashboards were designed for each academic department (Statistics, Mathematics, and Computer Science) as well as for the entire faculty. The results of this research demonstrate that the use of interactive management dashboards has yielded numerous benefits, including precise and timely monitoring of the faculty's strategic objectives, identification of strengths and weaknesses, facilitation of data-driven decision-making, increased transparency and accountability, and improved efficiency and effectiveness of faculty activities. Overall, this study indicates that the application of modern technologies such as data visualization can significantly contribute to enhancing management and planning in academic environments.

Keywords: Data Visualization, Dashboard, Strategic Plan, Key Performance Indicators, SMART, Usability, Allameh Tabataba'i University

1- INTRODUCTION

In today's data driven era, organizations require powerful tools to analyze vast amounts of data and make informed decisions in order to maintain their competitiveness and achieve their strategic goals. Interactive dashboards, which provide a comprehensive and visual overview of data, have emerged as one such powerful tool. These dashboards assist managers in identifying trends, patterns, and opportunities, ultimately leading to improved organizational performance. Universities, as educational and research institutions, also leverage these tools to enhance service quality, increase efficiency, monitor their KPIs and achieve their long-term objectives. This research aims to evaluate the role of interactive strategic dashboards in improving the decision-making process within the Faculty of Statistics, Mathematics, and Computer Science at Allameh Tabataba'i University. By utilizing the dashboards developed in this study, the faculty's key performance indicators can be accurately and effectively measured and monitored, enabling data-driven strategic decision-making. This will assist the faculty in achieving its goals and attaining a competitive position in higher education.

This research, with a focus on the faculty's strategic plan, endeavors to initially identify key performance indicators and align them with the SMART goal-setting model. Subsequently, a comprehensive interactive dashboard is designed and implemented using data visualization tools. This dashboard allows faculty managers to gain a comprehensive overview of the faculty's current status, trends, and key performance indicators growth. Furthermore, through in-depth data analysis, the faculty's strengths and weaknesses can be identified, and improvement strategies can be proposed.

Ultimately, the findings of this research can serve as a model for other faculties and universities to enhance their decision-making processes and improve the quality of their educational and research services. The subsequent sections of this paper will delve deeper into each of these aspects.

2- LITERATURE REVIEW

In this section, we will first introduce the basic concepts and definitions, followed by a review of the existing literature on this topic, including scholarly articles and theses.

2-1 Basic concepts and definitions

The definitions of the most important concepts related to business intelligence and data visualization required for this study are as follows:

Business Intelligence: Business Intelligence encompasses a range of technologies, applications, and methodologies employed for the collection, integration, analysis, and dissemination of business information. The fundamental objective of BI is to facilitate data-driven decision-making within organizations [1].

Data Visualization: Data visualization involves the utilization of visual representations to explore, comprehend, and communicate data. It is intimately connected to the disciplines of information visualization, information graphics, scientific visualization, and statistical graphics. Business intelligence systems incorporate a diverse array of data displays and interactive methods, including reports (static and dynamic), digital dashboards, and sophisticated visual analytics tools [1].

Strategic Planning: A strategic plan constitutes a strategic document formulated by organizations that delineates goals, actions, and strategies to attain long-term objectives and establish the organization's overall direction. This plan is typically developed at a macro level for one or more years and provides a detailed specification of the organization's long-term goals [2].

Key Performance Indicators (KPIs): A KPI is a measurable value that demonstrates how effectively a company is achieving key business objectives. Organizations use these metrics to evaluate their success in meeting their goals [3].

Management Dashboard: A management dashboard is a visual tool that helps managers and management teams within an organization to graphically display important information and key performance indicators. The advantage of using management dashboards in organizations is that by providing key information in real-time and interactively, it enables the rapid and accurate monitoring and tracking of organizational performance [4].

Decision-making Process: Decision-making is a process in which one of two or more alternatives is selected to achieve one or more objectives. Managerial decision-making is synonymous with the entire management process [1].

SMART Model: The SMART model in key performance indicators is a systematic approach used to define and set performance metrics. SMART is an acronym for Specific, Measurable, Achievable, Relevant, and Time-bound [5].

Usability: Usability in management dashboards refers to the simplicity and user-friendliness of the dashboard's features and design. This important feature facilitates access to information and performance indicators, reduces training time and costs, and minimizes the need for technical skills. Through a simple user interface and easy access to information, users can quickly and accurately conduct analyses and make strategic decisions [6].

ETL Process: ETL stands for Extract, Transform, and Load. It is a process used when building data warehouses. It involves collecting data from one or more sources, cleaning and transforming the data, and finally loading it into the data warehouse [1].

Data Warehouse: A data warehouse is a centralized repository for collecting, storing, and managing organizational data. This system collects data from various sources and stores it in a unified and structured manner in a centralized location [1].

2-2- Related Researches

Numerous studies have been conducted on the visualization of key performance indicators (KPIs) using dashboard approaches in organizations. Frady et al., in their paper titled "Decision Support in Engineering Design Based on Shared Dashboards: Integrating Business and BI Techniques," examined the analysis of data and the creation of actionable and profitable information for project monitoring and decision-making. The study employed an information technology architecture to implement the approach, combining three business process modules (involving multiple actors and data sources). Key findings include the extraction of KPIs from various data sources and their visualization using business intelligence techniques, particularly data visualization and dashboard techniques. However, the study lacked a specific approach for selecting KPIs and did not compare different visualization tools [7].

Kulichkov and Shchobotinov (2019), in their paper titled "Using Business Intelligence Tools for Visualizing KPIs of a Telecommunications Company," investigated the practical application of visual analytics tools for decision-making, focusing on visualizing large volumes of data using business intelligence tools. They visualized KPIs as a tool for supporting managerial decisions and building business models in technology companies using visual models. They concluded that visualizing KPIs significantly impacts the measurement of performance efficiency and the evaluation of the effectiveness of developing selected activities. A limitation of this study is the lack of consideration for design principles in dashboard development [8].

In another study, Zdonk (2020), focusing on "Visualizing Metrics Using an Interactive Dashboard," designed specific dashboards to display project metrics aimed at increasing their understandability, usability, and customization. The study used previous research to identify dashboard design principles and then created a real-world project management dashboard to investigate technical challenges and solutions for creating a useful tool to support project team work. The study concluded that important factors for dashboard comprehensibility include an appropriate number of charts, selecting suitable charts based on data and required actions, and color design considering color-impaired users. Additionally, the dashboard should provide usability (scannability) for users, and time elements and filtering should be added. For customization, the dashboard should display project metrics based on the project team's tasks. A limitation of this study is the lack of a specific method for selecting project metrics [9].

Pila (2017), in their thesis titled "Analysis of Key Performance Indicators and Dashboard Visualization in a Logistics Company," focused on identifying and visualizing key performance indicators in the logistics sector to optimize processes. The research employed performance measurement and data visualization theories to create operational models and dashboard planning. The study identified suitable performance indicators for various processes and user needs, and developed operational and planning dashboard models adaptable to the specific company. By utilizing data visualization, performance measurement was improved, and the sharing of appropriate indicators with specific user groups was facilitated [10].

Ramprasad (2019), in their research titled "Selection and Visualization of Key Performance Indicators in Product Development," emphasized the importance of performance measurement and the use of KPIs in various industries. This research explored how KPIs can be leveraged in product development and how dashboards can be used as tools

for visualizing and linking them to organizational strategy and performance. The study identified key factors in selecting and visualizing KPIs for communication with stakeholders at various levels of the organization. Furthermore, a framework for dashboard development was presented based on five key factors, along with guidelines for the successful development and acceptance of effective dashboards using the technology acceptance model. The thesis concluded that by using KPIs and dashboards, organizations can establish effective communication with stakeholders and develop, adopt, and implement effective dashboards [11].

Poll (2022), in their thesis titled "Visualizing Company Performance Using Dashboards," developed management dashboards for Peddler, a startup selling local store products through an online platform. The research involved a systematic literature review and the use of various methods and tools for data analysis to develop suitable dashboards. Additionally, through multiple interviews, accurate information about the company was collected, and appropriate performance indicators were provided for evaluation. The use of various dashboards in this research led to significant results. Some of the results included allocating appropriate timeframes to postal codes, analyzing the performance of different cities and regions, and examining the performance of stores and couriers. However, one of the limitations of this research was the lack of attention to usability principles in dashboard development, resulting in low usability [12].

Marella's 2023 thesis titled "Digitalization of Key Performance Indicators for Quality" underscores the significance of KPIs in business processes and the utilization of data analysis and visualization for informed decision-making. The paper employs various software tools to analyze data and create diverse visualizations, such as line charts, bar charts, Pareto charts, and scatter plots. Additionally, the study examines different software tools for data visualization and offers recommendations in this area. However, one limitation of this study is the absence of a clear and systematic method for selecting KPIs within the case study [13].

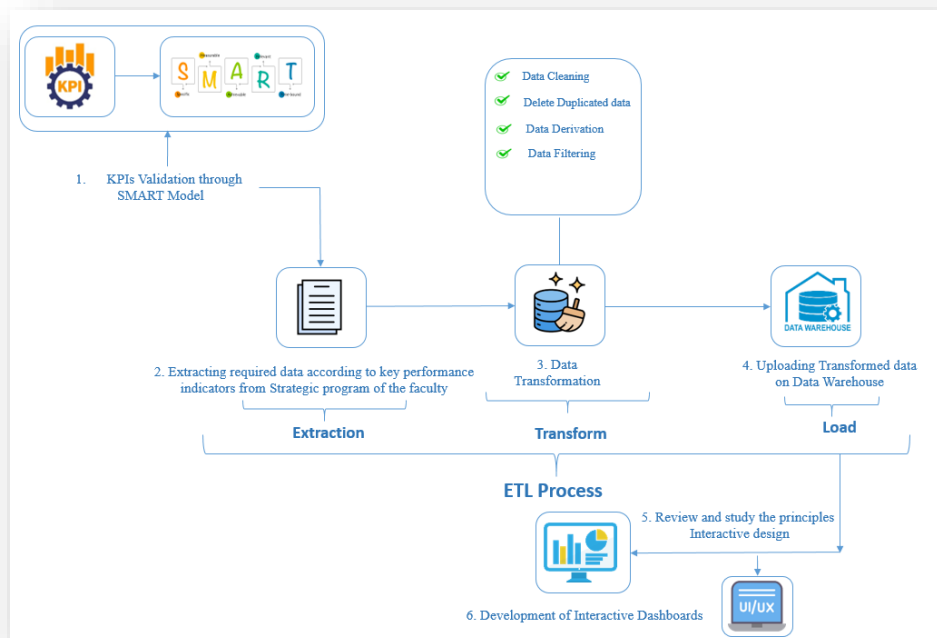


Figure 1. Research Phases

3- METHODOLOGY

In this research, key performance indicators (KPIs) will be identified based on the objectives outlined in the faculty's strategic plan and using the SMART framework. Data required for these KPIs will be collected from various sources, such as university information systems and surveys. After data extraction and transformation, the data will be loaded into a cloud-based data warehouse. Finally, using this data, management dashboards will be designed and implemented to enable managers to make informed decisions and continuously monitor the faculty's performance. Figure 1 provides an overview of the research process.

Stage 1: Selecting Key Performance Indicators (KPIs) based on the SMART Model: The SMART model, a well-known framework for goal setting, will be used to identify suitable KPIs. SMART stands for Specific, Measurable, Achievable, Relevant, and Time-bound.

Stage 2: Extracting Required Data Aligned with KPIs from the Faculty's Strategic Plan: Data extraction is the initial phase of the ETL (Extract, Transform, Load) process. For this research, the faculty's strategic plan will be analyzed to gather necessary data. The required data will be stored in suitable formats such as Word and Excel files.

Stage 3: Data Transformation: Data transformation is a critical step in the ETL process. This stage involves cleaning, aggregating, filtering, deriving, enriching, and removing duplicate raw data before processing and analysis.

Stage 4: Data Loading: After data transformation, the extracted and refined data from various sources will be loaded into the data warehouse. In this stage, data is loaded into the data warehouse without any changes from the intermediate environment. Different architectures (such as three-tier, two-tier, independent data marts, data mart bus architecture, hub and spoke, centralized, and federated) can be used for data warehouse design. Based on organizational needs and data processing volume, a centralized architecture will be designed and the data warehouse will be hosted on Google Sheets.

Stage 5: Reviewing and Studying Interaction Design Principles: Interaction design principles play a crucial role in dashboards and can significantly impact user experience and organizational efficiency. An interactive dashboard allows users to actively engage with organizational data and make better decisions. Therefore, in this stage, dashboard design principles will be examined for application in the subsequent dashboard development stage.

Stage 6: Designing Management Dashboards for the Organization Considering Interaction Design Principles: In this stage, data previously extracted, transformed, and loaded into the data warehouse will be visualized using Power BI, a data visualization tool ranked as the top data visualization tool in 2023 by Forbes. The data visualized in this dashboard will be the KPIs from the faculty's strategic plan.

3-1 Data

This research utilizes data obtained from the strategic plan of the Department of Statistics, Mathematics, and Computer Science at Allameh Tabataba'i University. The dataset encompasses both quantitative and qualitative information pertaining to the department's key performance indicators over a three-year period (2023, 2022, and 2024). By analyzing this data, it is possible to examine trends in the indicators and identify the department's strengths and weaknesses."

3-2 Method

SMART Model: To evaluate key performance indicators, the SMART model was employed. This model assists in selecting and examining specific, measurable, achievable, relevant, and time-bound indicators. The SMART model is a framework for setting objectives, and in this research, it was applied to assess the faculty's key performance indicators. This model helps ensure that the selected indicators for evaluation are specific, measurable, achievable, aligned with the faculty's overall objectives, and have a defined timeline. By utilizing this model, we can more accurately evaluate the faculty's progress towards achieving its strategic goals.

3-3 Tools:

- 1- **Google Sheets** (for data loading into the dashboard): A free, web-based tool for creating, editing, and sharing spreadsheets. It serves as an alternative to Microsoft Excel, allowing users to access and analyze data using a web browser. Key features of Google Sheets include:
 1. Creating and editing spreadsheets: Users can create new spreadsheets, input and edit data, utilize formulas and functions for calculations, generate charts and graphs, and more.
 2. Real-time collaboration: Multiple users can simultaneously work on a spreadsheet and view changes instantly.
 3. Cloud storage: Spreadsheets are automatically saved to the cloud, allowing access from anywhere.
 4. Offline access: The Google Sheets app provides offline access to spreadsheets.
 5. Free: Google Sheets is entirely free, requiring no paid subscription.
- 2- **Microsoft Power BI** (for final dashboard development): A widely used tool for data analysis and visualization provided by Microsoft. It can collect data from various sources such as databases, Excel files, web services, and more, allowing users to analyze data and visualize it as charts and tables using a simple graphical user interface. This tool also supports publishing analytical reports online and creating analytical dashboards. Additionally, users can quickly analyze their data and create high-quality, visually appealing charts. Another advantage is its ability to connect with other Microsoft tools like Excel and SharePoint, enabling users to quickly and easily utilize their data in various areas such as analysis, visualization, and data presentation [14].

4- RESULT AND DISCUSSION

In this section, the results obtained from data analysis are presented in detail, followed by an interpretation and discussion of these findings.

4-1 Case study

Allameh Tabataba'i University is one of the most prestigious universities in Iran and the region, recognized as the country's sole specialized institution for humanities and social sciences. While its foundations date back 60 years, the university was officially established in 1984, following the Islamic Revolution, to address the growing need for a specialized institution in the humanities and social sciences. It was formed by merging various independent educational institutions, including universities, faculties, research centers, and institutes, that had been established since 1958.

The Faculty of Statistics, Mathematics, and Computer Science of Allameh Tabataba'i University comprises the departments of Statistics, Financial Mathematics, and Computer Science. Its initial activities began in 1989 with the approval to establish a statistics program within the Faculty of Economics. In 1997, the first Master's program in Economic and Social Statistics was launched, followed by programs in Financial Mathematics and Computer Science in subsequent years. The faculty officially commenced its operations as an independent entity in 2013 [15].

4-2 Structure of Computer Science Faculty Strategic Plan

The operational program of this faculty, encompassing a diverse set of targeted activities, outlines a roadmap for enhancing the academic, research, and educational standards of the faculty. This program encompasses various activities such as organizing academic conferences and seminars, publishing books, conducting training workshops, fostering academic leadership among faculty members, and collaborating with other faculties and scientific centers. These activities are designed to enhance the knowledge and skills of faculty members and students, promote the production and dissemination of knowledge in the humanities, and establish connections with the scientific community and the general public" [15].

4-3 Validation of KPIs based on SMART Model

In this research, given the significance of selecting appropriate key performance indicators (KPIs) to evaluate faculty performance aligned with the strategic plan, the SMART model was employed as a comprehensive framework. To identify these KPIs, a previous study (Rashidi et al., 2023) conducted at the same university on a similar topic was consulted. This study extracted a set of KPIs based on the university's strategic plan. Considering the validity and alignment of the extracted KPIs with the university's conditions and objectives, this research also adopted these KPIs as key performance indicators at the faculty level of Statistics, Mathematics, and Computer Science, which are as follows:

- Book publications
- Domestic article publications
- International article publications
- Promotional chair sessions
- Problem-solving workshops
- Implementation of educational projects
- Startup establishment
- Organization of promotional chair sessions, workshops, and conferences
- Other programs [16].

In this study, considering the nature and level of research activities, the KPIs "intra-faculty research projects," "intra-university research projects," and "extra-university research projects" were considered as replacements for the general indicator "other programs." This change was made for reasons such as greater measurement accuracy, reflecting existing realities, and facilitating data analysis. The final KPIs with their definitions are presented in Table 3.

Table 1. KPIs of Faculty

No	KPIs	Definition
1	Book publications	Production and publication of a comprehensive written work in the relevant field.
2	Domestic article publications	Publication of research articles in domestic scientific journals.
3	International article publications	Publication of research articles in international scientific journals.
4	Promotional chair sessions	Organizing meetings and discussions on scientific and research topics to promote knowledge.
5	Problem-solving workshops	Holding specialized meetings to analyze and solve problems in various fields.
6	Implementation of educational projects	Implementing educational and research programs to enhance the academic level of students and faculty.
7	Startup establishment	Establishing startups and knowledge-based companies to commercialize innovative ideas.
8	Organization of promotional chair sessions, workshops, and conferences	Organizing various scientific and research events to promote knowledge and foster interactions among researchers.
9	Intra-faculty research projects	Implementing research projects within the faculty using internal resources.
10	Intra-university research projects	Implementing research projects at the university level in collaboration with other faculties and research centers.
11	Extra-university research projects	Implementing research projects in collaboration with external institutions and organizations.

The SMART model is a robust framework for setting and assessing goals [17]. To verify the alignment of the chosen indicators with this model, Table 2 was employed. This table facilitates a rigorous and clear validation of each indicator across the model's five fundamental dimensions.

Table 2. Validation of KPIs according to SMART model

KPI(s)	Specific	Measurable	Achievable	Relevant	Time-bound
Book publications	refers to the production and publication of a complete written work.	The number of published books is countable.	This is achievable given the available resources and support.	This is important for enhancing the academic reputation of both the author and the faculty.	A specific timeline can be set for the publication of each book.

Domestic article publications	refers to the publication of articles in domestic journals.	The number of articles published in domestic journals is countable.	This is achievable considering the research activities of the faculty members.	This is important for improving the academic level of the faculty and disseminating research findings.	A specific timeline can be set for the publication of articles.
International article publications	refers to the publication of articles in international journals.	The number of articles published in international journals is countable.	This requires more effort and high-quality research.	This is crucial for enhancing the faculty's international ranking and the visibility of its researchers.	A specific timeline can be set for the publication of articles in international journals.
Promotional chair sessions	refers to holding lectures, discussions, and exchanges of ideas.	The number of meetings held and the number of participants are countable.	This is achievable given the available human resources and facilities.	This is important for promoting knowledge and fostering interaction among researchers.	The number of meetings and their schedules can be determined.
Problem-solving workshops	refers to holding specialized meetings to solve problems.	The number of meetings held and the number of participants are countable.	This is achievable considering the identified problems and the availability of experts.	This is important for improving the faculty's performance and addressing challenges.	The time of meetings and the topics to be discussed can be determined.
Implementation of educational projects	refers to the implementation of educational programs.	The number of training courses conducted, the number of participants, and the number of training hours are measurable.	This is achievable given the educational needs and available resources.	This is important for enhancing the academic level of students and faculty members.	The start and end times for each training program can be determined.
Startup establishment	refers to the establishment of startups.	The number of startups created and the amount of investment attracted are measurable.	This requires financial support and appropriate facilities.	This is important for commercializing innovative ideas and generating revenue for the faculty.	A specific timeline can be set for the launch of each startup.
Organization of promotional chair sessions, workshops, and conferences	refers to organizing various scientific events.	The number of events held, the number of participants, and the topics discussed are measurable.	This is achievable given the available resources and facilities	This is important for promoting knowledge and fostering interaction among researchers.	An annual events calendar can be established.

intra-faculty research projects	refers to the implementation of research projects within the faculty.	The number of projects implemented, the budget spent, and the results achieved are measurable.	This is achievable given the faculty's internal resources.	This is important for strengthening both fundamental and applied research within the faculty.	The start and end times for each project can be determined.
Intra-university research projects	refers to the implementation of research projects at the university level.	The number of projects implemented, the budget spent, and the results achieved are measurable.	This requires collaboration with other faculties and research centers.	This is important for strengthening interdisciplinary collaborations and enhancing the level of research at the university.	The start and end times for each project can be determined.
Extra-university research projects	refers to the implementation of research projects in collaboration with external institutions.	The number of projects implemented, the budget spent, and the results achieved are measurable	This requires connections with institutions outside the university and attracting external funding.	This is important for establishing connections with industry and society and enhancing the university's reputation.	The start and end times for each project can be determined.

As seen in the table, all selected indicators align with the various dimensions of the SMART model. This indicates that the indicators are well-defined and can be used for accurate performance evaluation.

4-4 ETL Process

To measure the faculty's progress in achieving the strategic plan of the university and the faculty's operational plan, the required data was extracted from Word and Excel files containing the faculty's operational plan. This data included information about the faculty's activities centered around key performance indicators (Table 1), activity executors, activity timeline, and so on. Initially, the data was extracted from Word and Excel files, and after data cleaning and removal of duplicates, it was integrated into a unified database (Google Sheets).

4-5 Interactive Design Principles

Interactive dashboard design, as a powerful tool for data analysis and decision-making, holds significant importance. For an interactive dashboard to function effectively and convey information efficiently to users, adhering to specific principles is essential. Table 3 presents the most important principles of interactive dashboard design in terms of usability, outlined in bullet points along with definitions and examples [18].

Table 3. Most Important Interaction Design Principles

Principle	Meaning	Example
Simplicity and fluency	The dashboard should have a simple, clean, and uncluttered design. Visual elements should be chosen so that information is easily understandable.	Use of appropriate colors, legible fonts, and a well-organized layout of elements on the page.
Focus on the goal	The dashboard should have a clear purpose and answer specific questions. The information presented should be relevant to the users' needs.	The dashboard should focus specifically on key performance indicators (KPIs) in an organization.
High interactivity	The dashboard should allow users to easily interact with the data. This includes filtering, sorting, zooming, and panning the data.	The ability to filter data based on date and other important parameters should be available.
Alignment with user cognition	Dashboard design should be based on an understanding of users and how they interact with information. Familiar terms and symbols should be used.	Use bar charts to show comparisons between groups, as this type of chart is familiar and understandable to users.
Compatibility with various devices	The dashboard should display well and be usable on various devices such as desktop, tablet, and mobile.	Design the dashboard using responsive frameworks that automatically adapt to screen size.
Providing information at a glance	The most important information should be conveyed to the user at first glance. Use charts and key performance indicators to display information quickly and easily.	Display the most important information in a large, prominent box at the top of the dashboard.
Meaningful use of colors	Colors should be used meaningfully and to convey specific information. Use a harmonious and distinguishable color palette.	Use the color red to indicate a decrease in growth and green to indicate an increase in growth.
Automatic updates	The dashboard should update automatically so that users always have access to the latest information.	Connect the dashboard to a database and schedule automatic updates at specified intervals.

4-6 Dashboard Development Process

The development process stages should progress from requirements elicitation, where dashboards are built to understand informational needs and how to present them, to dashboard maintenance, where maintenance and corrective support activities are performed. An overview of the stages is presented in Figure 4



Figure 2 – Dashboard Development Process Phases

Requirements Elicitation:

The goal of this stage is to gather high-level expectations for the dashboard and create initial content designs. Dashboard designers should identify stakeholders, information providers, and dashboard users within the organization by conducting interviews. The outcome of this stage is an information model for the dashboard's indicators and a preliminary visual content design.

Dashboard Type Selection:

The goal of this stage is to find the appropriate technology for dashboard implementation. The outcome of this stage is the first dashboard prototype as a proof of concept for the technology.

Dashboard Design:

Depending on the selected technology, designers must iteratively design and evaluate the dashboard. We recommend the concept of a minimum viable product (MVP) and the build-measure-learn approach for this stage. This stage should conclude with an operational dashboard that meets the initial requirements.

Impact Assessment:

After implementing the dashboard, designers should observe its impact on the organization. For this purpose, organizational learning theory by Goodman and Dean is recommended. A successful dashboard in this regard will show signs of influencing company performance, which will be evident in dashboard indicators/metrics after introducing changes.

Dashboard Maintenance:

The final stage is dashboard maintenance, where the designer or a dedicated person monitors the operational dashboard and ensures it displays the required information. The designer must also be involved in updating the dashboard as company goals or data sources change over time. The design and maintenance of dashboards depend on the chosen technology, so designers should assess the organization's needs and carefully select the technology. [19]

4-7 KPIs Interactive Dashboard

To better understand how this dashboard works, we will now examine images of its key pages. These images visually demonstrate how the dashboard transforms complex data into understandable and actionable information. Figure 3 shows an image of the dashboard's homepage where, at this stage, the user selects the desired dashboard based on their needs.

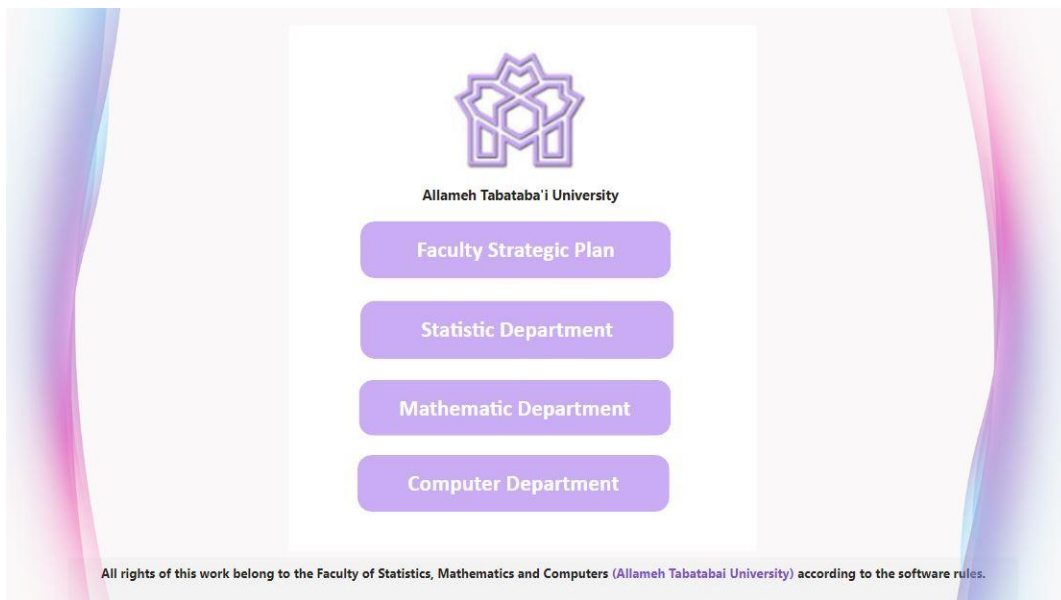


Figure 3. The First Page of Dashboard

Figure-4 presents a view of the dashboard's homepage, where the entire operational program of the faculty is visualized. The diverse charts on this page display information such as: the increase or decrease in growth of 11 key performance indicators of the faculty, the growth trend of these indicators over the past three years, the total number of faculty activities, the number of activities to achieve strategic visions and goals by indicator, the distribution of activities by executors (faculty members), the distribution of activities by seasons, and the type of activity execution (individual or group)

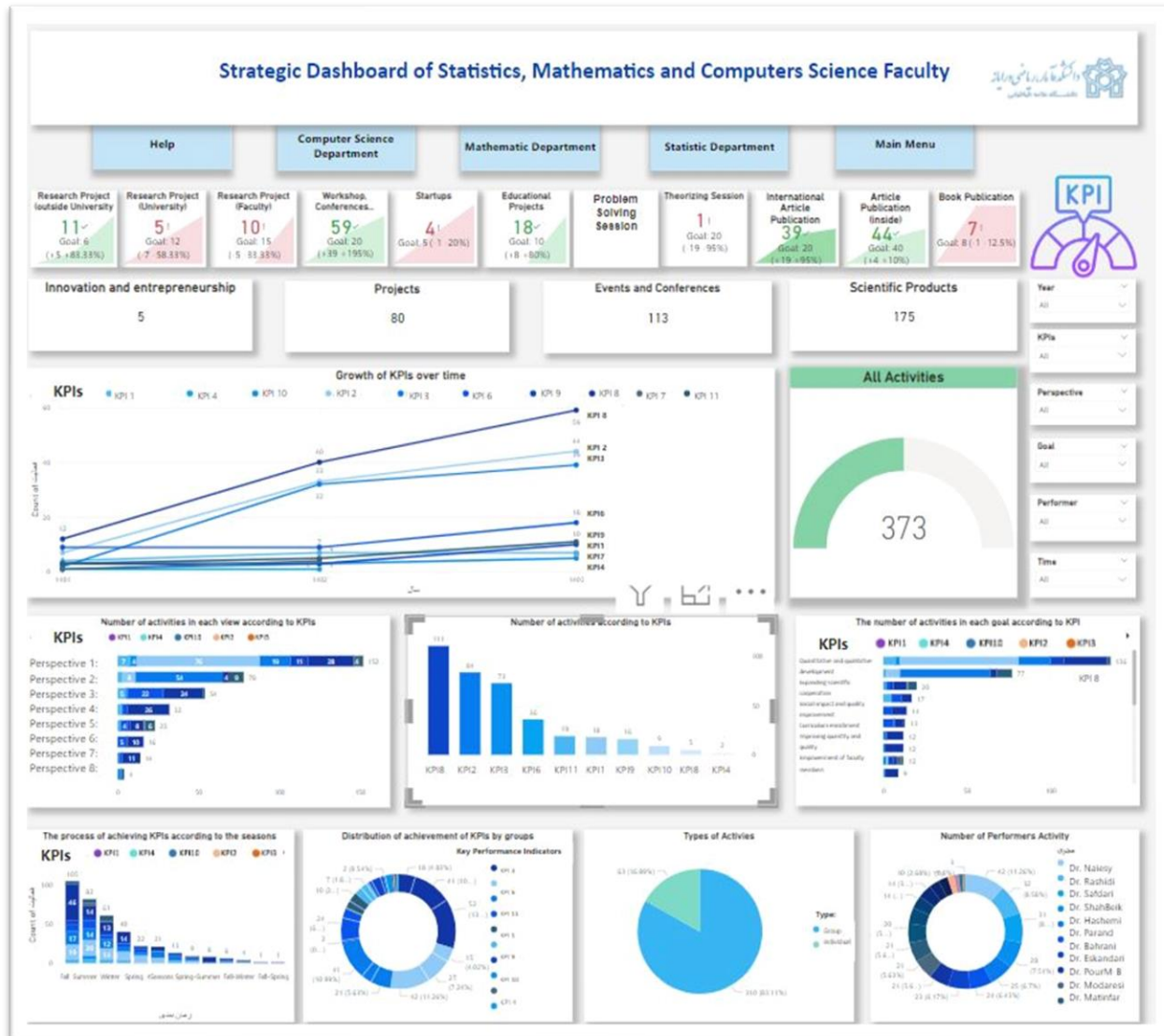


Figure 4. Main Page of Dashboard (Strategic Information about faculty)

Some of the important features of this dashboard page (Figure-4), according to the dashboard design principles mentioned in Table 3, are as follows:

1. Ability to filter and search data based on year, indicator, strategic aspect, goal, activity executor, and activity execution time (principle of high interactivity);
2. Use of specific charts for key performance indicators to show the increase or decrease in growth of each indicator using meaningful colors (principle of using colors meaningfully, green color to show growth increase and red color to show growth decrease);
3. Overall categorization of key performance indicators and use of card charts to display the number of activities in each indicator (principle of focusing on the goal);
4. Use of line charts to show the growth trend of indicators over different years (principle of alignment with user cognition);
5. Use of various charts such as bar charts, pie charts, line charts, stacked bar charts, card charts, donut charts, etc., based on the information (principle of alignment with user cognition);
6. Use of tooltips (brief guides in software) for each chart for greater clarity for the user (principle of simplicity and fluency);
7. Use of relevant and meaningful colors to display data (different color tones to indicate the quantity of a value (principle of using colors meaningfully));
8. Ability for the user to easily navigate between different dashboard pages (existence of buttons to go to other pages (principle of high interactivity));
9. Highlighting important and essential information and prioritizing their charts based on arrangement and font size (principle of presenting information at a glance);
10. Ability for the user to interact with each part of the charts in the dashboard (principle of high interactivity).

Figure 5 shows an example of the interactive feature of the dashboard. By clicking on the second column (second indicator: publishing internal articles), the chart (number of activities based on key performance indicators) changes all the charts on the dashboard page based on this data point (the second key performance indicator of the faculty), and information related to this indicator, such as the number of activities in this indicator, executors of activities, activity time, and more, are highlighted and displayed.

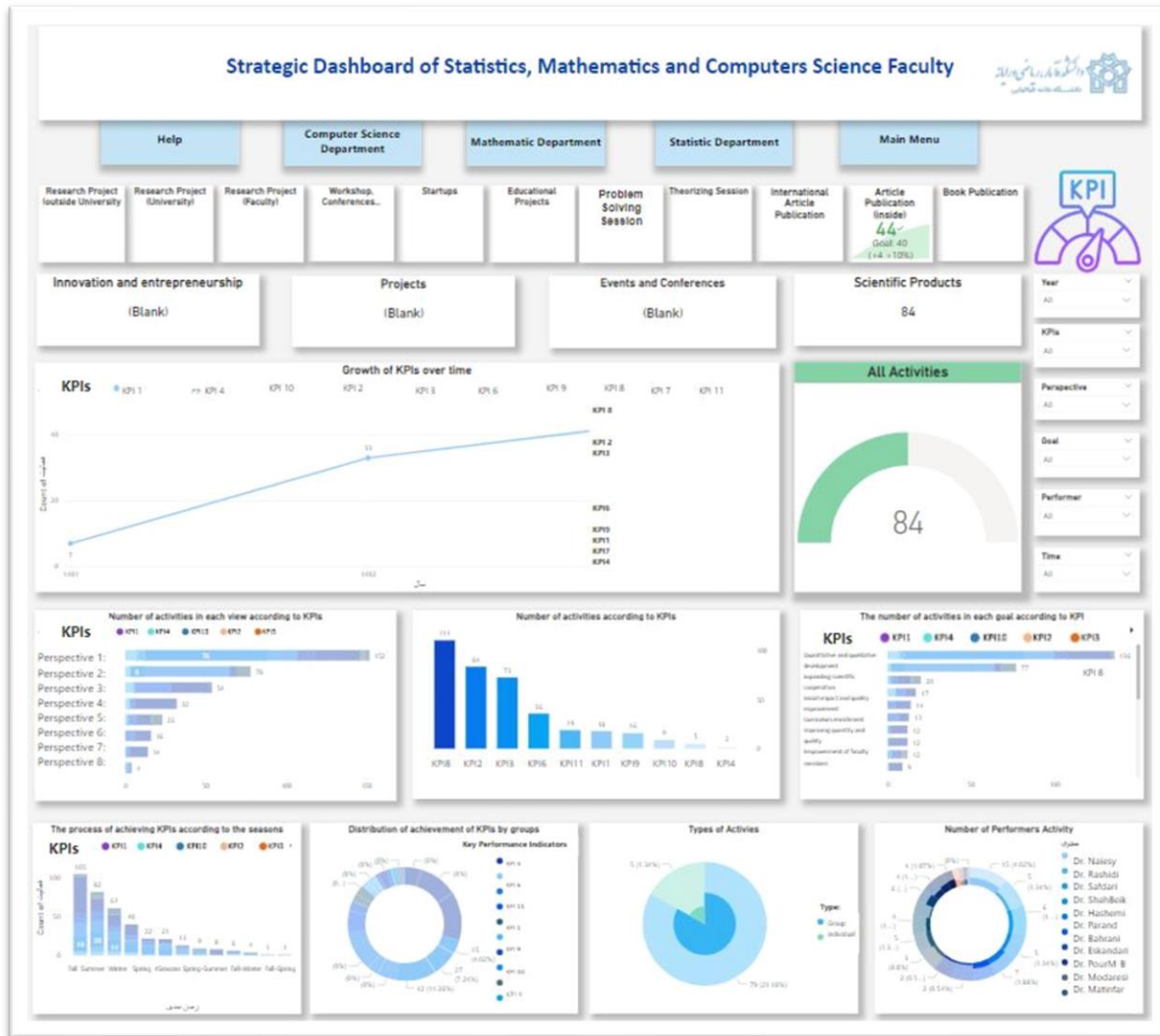


Figure 5. Interactivity of Dashboard

The main dashboard page, displayed in Figure 4, provides a comprehensive overview of the entire faculty's status. This page is intended to be the starting point for users and provides quick access to important information. The structure and visual elements present on this page serve as a template for other dashboard pages, each of which is designed specifically for individual groups (statistics, mathematics, and computer science). While maintaining overall consistency, these pages display the required information for each group in a customized manner.

5- CONCLUSION

The results of this research, focusing on a case study of the Faculty of Statistics, Mathematics, and Computer Science at Allameh Tabataba'i University, demonstrate that interactive dashboards, as a powerful tool, can play a significant role in improving the decision-making process in academic environments. By providing a visual overview of various faculty data, including key performance indicators and their growth trends, activities carried out to achieve strategic goals and visions, the level of faculty member activity, strengths and weaknesses of group and faculty activities, these dashboards enable organizational managers and decision-makers (in this research, the university) to quickly identify

trends and hidden patterns in the data. For example, by using a dashboard, it is easy to compare the performance of executors in various activities, identify the strengths and weaknesses of strategic planning, and consequently, make better decisions to improve the quality of the faculty. In addition, interactive dashboards, by reducing data analysis time and increasing decision-making accuracy, help faculty managers to quickly respond to environmental changes and take advantage of new opportunities. For instance, using a dashboard, it is easy to examine the trend of increasing or decreasing growth of key performance indicators and, as a result, plan better to achieve future strategic visions. Furthermore, dashboards, by providing a common language for communication between faculty members, managers, and other stakeholders, help improve collaboration and coordination within the faculty. By using a dashboard, all faculty members can refer to a single, reliable source for the information they need, and as a result, make joint and data-driven decisions. In conclusion, the results of this research show that interactive dashboards can be used as a strategic tool to improve the performance of faculties and universities. By investing in the development and implementation of these tools, it is possible to increase efficiency, improve the quality of education and research, and ultimately enhance the university's position at the national and international levels.

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Analysis of bicycle traffic in the city and feasibility of bicycle routes in urban spaces (case example: Tehran)

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ABSTRACT

This study was conducted to analyze urban bicycle traffic and evaluate the feasibility of existing and potential bicycle routes in Tehran, addressing the need for sustainable urban mobility solutions in a rapidly urbanizing environment. The research aimed to identify key factors that could enhance the efficacy of bicycling as an effective transportation method within the city. Employing a mixed-method approach, primary data were gathered through surveys distributed among cyclists and interviews with urban planners, complemented by secondary data from Tehran's Transportation and Traffic Organization. Statistical analysis was performed using SPSS to discern patterns and trends in bicycle usage. The findings reveal a considerable disparity in the distribution of bicycle paths and stations, with significant infrastructural gaps impacting the practicality of cycling across Tehran. The analysis identified poorly connected routes and insufficient safety measures as major barriers, despite some regions having extensive bicycle infrastructure. The data also indicated a high willingness among non-cyclists to adopt cycling if improvements were made, highlighting the unexploited potential for growth in urban cycling. These results suggest that while Tehran has initiated steps towards integrating cycling into its urban framework, substantial efforts are required to make it a safer and more appealing option for everyday commuting. Future research should explore the socio-economic impacts of enhancing bicycle infrastructure and consider comparative studies with other cities to adopt best practices. The study underscores the necessity of strategic urban planning to foster a more inclusive cycling culture, aligning with broader development goals to ensure the sustainability and livability of Tehran. This research contributes to the urban transportation planning literature by providing a model for other Middle Eastern cities facing similar challenges, promoting sustainable transportation solutions that are culturally and contextually adapted to local needs.

Keywords: Bicycle, Bike Path, Urban Cycling Infrastructure, Sustainable Urban Transportation, Feasibility Study, Tehran

14. INTRODUCTION

Urban transportation systems are crucial in shaping environmental sustainability, economic resilience, and the overall quality of life in cities worldwide [1]. With the expansion of urban centers and the increasing demand for efficient mobility, the integration of non-motorized forms of transport, particularly bicycling, has emerged as a vital element in urban planning [2]. This integration is especially critical in densely populated cities, where traffic congestion and pollution pose significant challenges [3].

The rapid growth of urban populations and their corresponding mobility needs require innovative solutions that can alleviate the pressure on existing transportation infrastructures and mitigate environmental impacts [4]. In this context, bicycling not only serves as a practical mobility solution but also acts as a catalyst for promoting healthier and more sustainable urban living. By strengthening non-motorized transportation modes, cities can achieve multiple benefits: reducing carbon emissions, decreasing noise pollution, and enhancing the physical well-being of their residents [5].

Additionally, the human dimension of incorporating bicycling into urban transport is profound. Bicycling encourages a connection with the urban environment that motorized vehicles simply cannot provide. Cyclists

experience their cities more intimately, navigating the subtle nuances of their neighborhoods and engaging more directly with their communities. This mode of transport supports not only physical health but also mental well-being, providing a stress-relieving outlet and a sense of freedom in daily commutes [6].

The shift towards more bicycle-friendly cities requires thoughtful urban planning that considers both spatial and social aspects of transportation. This includes creating safe, accessible bicycle paths, secure bike parking facilities, and ensuring that cycling infrastructure is integrated with other modes of public transport. Such comprehensive planning helps foster a cycling culture, making it an attractive option for more individuals [7].

As we strive to make our cities more livable and environmentally sustainable, the role of non-motorized transportation, such as bicycling, becomes increasingly important. It is a testament to a city's commitment not only to its current inhabitants but also to future generations who will inherit a more resilient and vibrant urban landscape. By investing in and promoting bicycling, we are not merely planning for efficient transport; we are fostering a deeper, more harmonious relationship between people and their urban environments [8].

In Tehran, the capital and largest city of Iran, the challenges associated with urbanization and motorization are particularly acute. The city has rapidly transformed, experiencing a surge in motor vehicle use that has led to increased traffic congestion, air pollution, and noise. These issues do not merely detract from the environmental quality of the city; they also profoundly impact the health and well-being of its residents. In response, there is a growing interest in promoting bicycling as a sustainable alternative to motorized transport. However, despite these efforts, the infrastructure for bicycling remains underdeveloped, and the full potential of cycling as a mode of urban transport has yet to be fully realized [9].

The rapid urbanization of Tehran has brought a plethora of urban challenges that mirror a global crisis faced by many major cities, where infrastructure development lags behind the rapid proliferation of motor vehicles. This delay not only exacerbates environmental degradation but also intensifies the urban heat island effect, diminishes the quality of urban life, and restricts the mobility of residents.

The growing interest in bicycling reflects a broader recognition of its benefits, not only as a traffic congestion mitigator but also as a vital component of a sustainable urban future. Bicycling reduces dependence on fossil fuels, diminishes pollution, and offers a quiet, efficient mode of transport. However, realizing these benefits is contingent upon the availability of safe, accessible, and continuous cycling infrastructure. This includes dedicated bicycle lanes, secure bike parking, and supportive facilities that encourage more people to choose cycling over driving [10].

Moreover, integrating bicycling into Tehran's urban fabric necessitates a cultural shift—a reimagining of public spaces where bicycles are considered on par with motor vehicles in the urban hierarchy. Such a transformation could significantly strengthen the social fabric of the city, fostering more interactive, vibrant, and healthy urban communities.

Furthermore, the development of bicycle infrastructure in Tehran could serve as a model for other cities in Iran and the broader Middle East, demonstrating the feasibility and benefits of sustainable urban transport solutions in regions predominantly designed for motor vehicles.

In this context, promoting bicycling is not merely about infrastructure development; it is about cultivating a new urban ethos that values sustainability, health, and community. Tehran, by investing in bicycling, can pave the way toward a more livable city, where the well-being of its citizens is at the heart of urban planning initiatives. This not only addresses the immediate challenges of urban congestion and pollution but also contributes to the city's long-term resilience, offering a beacon of hope and a roadmap for other cities grappling with similar challenges [11].

Research on urban bicycle traffic and extensive infrastructure is widespread. However, there is a significant gap in localized studies, particularly in the Middle East, where urban dynamics can substantially differ from Western models. The existing literature often focuses on Western cities, which have a long history of bicycle-friendly urban

planning, thus overlooking the unique challenges faced by cities like Tehran. This research aims to fill this gap by providing a detailed analysis of Tehran's current bicycle infrastructure, identifying barriers to cycling, and suggesting possible improvements [12].

The objective of this study is to assess the feasibility and effectiveness of existing and potential bicycle routes in Tehran and to plan for enhancements that better accommodate urban cyclists. This involves understanding current usage patterns, cyclist behavior, and safety issues, as well as evaluating the connectivity and accessibility of existing cycling infrastructure [13].

While the Global North has extensively documented the integration of bicycling into urban landscapes as a strategy for sustainable city living, less attention has been paid to how these strategies can be adapted to the unique social, cultural, and infrastructural realities of cities in the Global South, particularly in the Middle East. Tehran represents a complex urban tapestry where traditional transport modalities coexist with a growing interest in sustainable urban mobility solutions. However, rapid urban expansion and motorization have outpaced the development of necessary infrastructure, making bicycling both a challenge and an opportunity for significant urban improvement [14].

In response to these challenges, this research not only highlights the shortcomings of Tehran's current bicycle infrastructure but also explores the potential for transformative change. By examining the interplay between urban planning and bicycling infrastructure, this study provides insights into the obstacles that hinder the integration of cycling into daily commutes and the opportunities that exist for making bicycling a more viable and safe transportation option [15].

Additionally, the findings of this study aim to contribute to the broader discourse on urban sustainability, providing a model for other Middle Eastern cities grappling with similar challenges. The proposed improvements in Tehran's bicycle infrastructure could serve as benchmarks for regional urban planning strategies, promoting healthier and more resilient urban environments [16].

This study, with a focus on Tehran, fills a significant gap in understanding how bicycle-friendly initiatives can be implemented in non-Western contexts, thereby expanding the geographical and cultural applicability of sustainable urban transportation theories. This underscores the importance of culturally and contextually informed approaches to urban planning that take into account the unique characteristics of each city. Ultimately, this research supports a more inclusive view of urban sustainability, one that embraces the diverse urban landscapes of cities around the world and seeks solutions that are equitable, feasible, and tailored to local needs [17].

Previous studies have often highlighted the numerous benefits of bicycling, including reducing traffic congestion, lowering pollution levels, and improving health outcomes. However, these studies have also pointed out numerous barriers to effective cycling infrastructure, such as the lack of safe and continuous bike paths, insufficient parking facilities, and cultural attitudes towards cycling. In Tehran, limited research has been conducted on the practical challenges of cycling, such as safety concerns and the suitability of infrastructure, which this study aims to address [18].

The remainder of this article is organized as follows: Section II provides an overview of data collection methods and describes the data analysis techniques employed. Section III presents the results of the data analysis, identifying key issues and opportunities within Tehran's cycling infrastructure. Section IV discusses these findings in the context of global best practices and offers recommendations for urban planning and policy-making [19]. Finally, Section V concludes with a summary of the research findings and suggestions for future research. This introduction sets the stage for a more detailed exploration of bicycle traffic and infrastructure planning in Tehran, aiming to contribute valuable insights into urban transportation planning and the practical implementation of sustainable transport solutions in similar urban environments [20].

Exploring these themes is crucial not only for enhancing Tehran's bicycle infrastructure but also for fostering a broader understanding of how sustainable transportation initiatives can be effectively integrated into rapidly

urbanizing cities. This research fills a significant void by providing empirical evidence and nuanced analysis that support the development of targeted strategies to overcome the cultural and infrastructural barriers currently hindering the adoption of bicycling in Tehran [21].

Through this academic inquiry, we seek to provide a comprehensive framework that other cities with similar challenges can adapt and apply, promoting a shift towards more sustainable urban mobility. By examining Tehran's approach to cycling infrastructure within the broader context of global urban planning practices, the study contributes to the ongoing discourse on sustainable cities and offers a pragmatic blueprint for other urban centers striving to reconcile growth with environmental and public health objectives [22].

This detailed examination not only foregrounds the challenges but also illuminates the path forward, advocating for policy interventions that can transform urban landscapes into more bicycle-friendly environments. Such changes are not merely infrastructural but also deeply cultural, requiring shifts in public perceptions and behaviors to embrace and support sustainable modes of transportation [23].

15. Method

This research employs a mixed-method approach for the collection and analysis of data on Tehran's bicycle infrastructure. The study is applied in nature and utilizes a descriptive-analytical method; primary data were collected through surveys distributed across the city and interviews with urban planners and cyclists. Secondary data were sourced from the Tehran Transportation and Traffic Organization and analyzed using SPSS software to understand trends and patterns in bicycle traffic. This methodology involves several distinct phases, each crucial for achieving the comprehensive analysis necessary for effective urban planning and development [24].

Primary data were initially collected using a library method, which included a systematic review of existing documents and records. This approach involved the analysis of academic articles, urban planning reports, and previous studies related to bicycle infrastructure and urban mobility, providing a solid foundation of secondary data. Key information was then gathered through structured interviews with urban planning experts, traffic management authorities, and stakeholders in bicycle infrastructure projects. These discussions provided insights into the challenges and opportunities within Tehran's current system.

Subsequently, questionnaires and surveys were distributed across the city to collect data directly from cyclists and residents. The questionnaires were designed to assess user satisfaction, frequency of use, perceived safety, and suggestions for improvements. Data related to the specifics of bicycle paths and stations, such as their lengths and locations, were collected directly from Tehran's Transportation and Traffic Organization. This information is crucial for mapping the existing infrastructure and identifying underserved areas. The collected data were subjected to rigorous statistical analysis using advanced methods and techniques. The use of statistical software, particularly SPSS, facilitated the quantitative analysis of the data. This phase involved descriptive statistics to summarize the data, as well as inferential techniques to conclude the population based on the sample data.

The integration of findings from both qualitative insights and quantitative data analyses provided a robust basis for evaluating the current state of Tehran's bicycle routes [25]. It also aided in formulating targeted recommendations for enhancing the city's bicycle infrastructure. Overall, this methodologically rigorous approach ensures that the research conclusions are well-supported by empirical evidence, providing a dependable foundation for policy-making and strategic planning in urban transportation.

16. Result

This study employs a comprehensive approach to analyze bicycle traffic and the viability of existing and planned bicycle routes in the city of Tehran. By examining the current infrastructure and the potential for future enhancements, this research seeks to identify key factors that can improve the effectiveness of bicycling as a viable mode of transportation in Tehran. The primary issue addressed was the inadequacy of Tehran's current bicycle infrastructure to

meet the demands of its users, potentially hindering the adoption and benefits of bicycling in a densely populated urban environment. The study focused on assessing these infrastructural elements to provide practical insights for urban planners. Data analysis led to several significant findings:

1. **Spatial Distribution of Bicycle Paths:** Analysis of current bicycle paths through field surveys showed a significant lack of connectivity. Many bicycle paths are isolated from each other, creating fragmented routes that do not support comprehensive travel across the city. Additionally, despite higher traffic density, central areas of Tehran have fewer cycling paths compared to some less dense outskirts, which contradicts typical urban planning logic.
2. **Safety and Accessibility:** Survey results indicated that the majority of cyclists feel unsafe using the existing paths due to proximity to motor vehicle traffic and poor path maintenance. Moreover, a high percentage of non-cyclists expressed willingness to take up cycling if improvements were made to the safety and connectivity of bicycle paths.
3. **Usage Patterns:** Data collected from bicycle stations demonstrated peak usage during early mornings and late afternoons, aligning with commuter patterns. However, weekend usage was notably lower than expected, suggesting recreational use is minimal.

The findings of this study indicate that while Tehran has made strides toward integrating bicycle infrastructure into its urban landscape, much remains to be done to make cycling a safe, convenient, and attractive mode of transportation. The unexpected willingness among non-cyclists to start cycling if conditions improve suggests a significant potential for growth in this mode of transit, provided that the city addresses the current shortcomings in safety and network design.

Overview of Bicycle Infrastructure Analysis in Tehran

- The length of cycling routes varies significantly, ranging from about 4.55 km to 41.02 km across different regions. The number of bicycle stations also varies, from 0 in some regions up to 19 in others.
- The analysis showed a significant variability in the distribution of bicycle paths. Some regions, notably region 2, have extensive paths (over 41 km) and a high number of stations (19), suggesting a potential focus on these areas for cycling activity. Table 1 also shows a mismatch between the location of bicycle stations and the regions' population density and commuting patterns, as some densely populated regions have few stations.

Table 1: The length of the bike path and The Bicycle station in Tehran

The length of the bike path (Km)	Bicycle station (Number)	Regions
6.318	3	1
41.022	19	2
7.419	3	3
8.333	3	4
24.679	11	5
21.907	38	6
5.73	9	7

24.627	0	8
15.765	2	9
4.547	1	10
6.698	5	11
12.271	2	12
19.494	3	13
6.626	2	14
14.175	17	15
13.548	4	16
5.094	3	17
7.305	8	18
12.025	3	19
19.104	5	20
13.879	6	21
41.663	8	22
332.229	155	total

Figure 1 shows a bar graph summarizing the number of bicycle stations by region, highlighting disparities in cycling support infrastructure, meaning that despite extensive infrastructure in certain areas, overall connectivity across the city remains poor, leading to underutilization in areas with extensive facilities. Data demonstrates that while Tehran has made efforts towards promoting bicycling, the infrastructure is unevenly distributed and not always aligned with the needs of potential users.

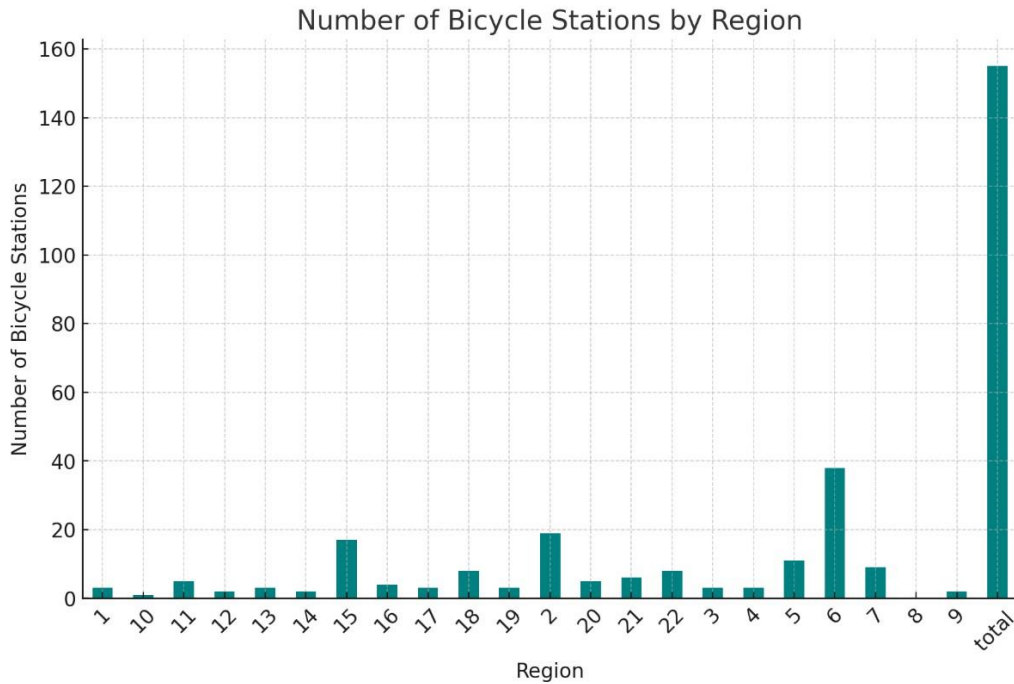


Figure 1: Number of Bicycle Stations by Region

Figure 2 displays a map of bicycle path lengths by region, visually depicting the distribution and highlighting areas with extensive versus limited infrastructure. The bar chart of bicycle stations by region, which is a bar graph showing the number of bicycle stations in each region, emphasizes the existing differences in infrastructure provision. The blue bars represent the length of bicycle paths in kilometers for each region. The red line shows the number of bicycle stations in each region, plotted against the right y-axis. These visualizations clearly illustrate the comparison between physical infrastructure (path length) and support infrastructure (number of stations) across different regions in Tehran, showing significant variations.

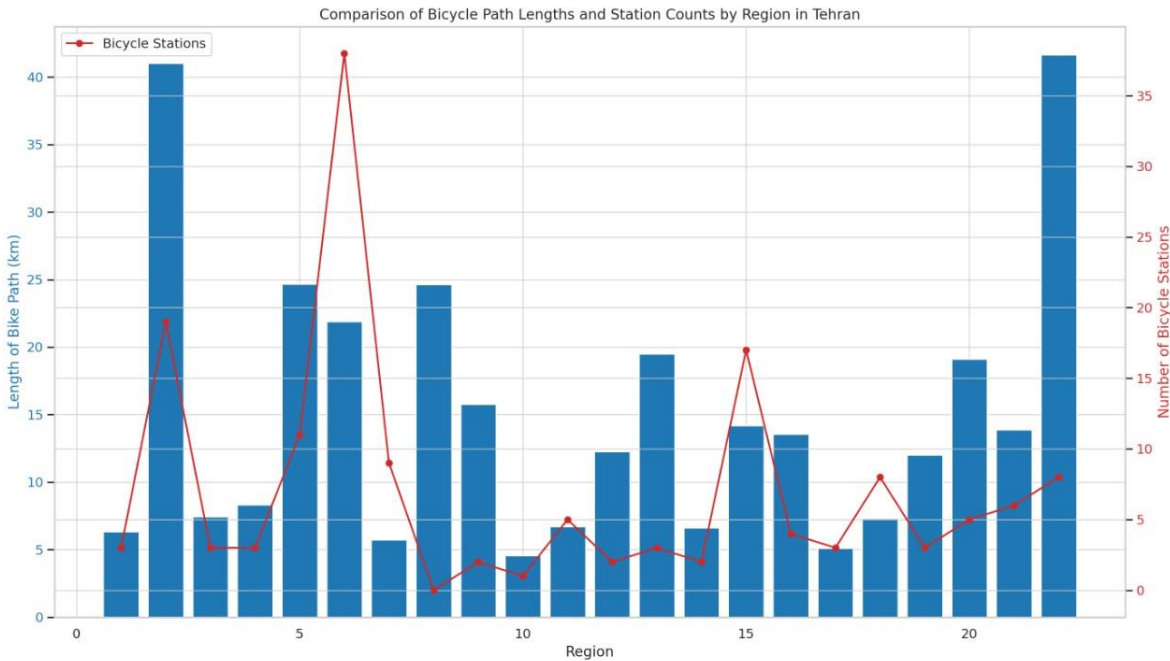


Figure 2: Comparison of Bicycle Path Lengths and Station Counts by Region in Tehran

4. Conclusion

This study meticulously examines the distribution and efficiency of bicycle infrastructure in Tehran, providing valuable insights that enhance the understanding and strengthening of urban cycling dynamics. Integrating quantitative data on the lengths of bicycle paths and station availability with qualitative feedback from users, this research fills a significant gap in the literature on urban transportation planning, particularly within the context of Middle Eastern cities. The findings indicate a considerable disparity between the distribution of paths and bicycle stations across Tehran, highlighting a substantial imbalance that affects the practical usability of urban cycling infrastructure. While specific areas boast extensive paths, the overall connectivity and safety measures are lacking, limiting the potential of bicycling to become a more dominant mode of urban transportation. Notably, the unexpected readiness of non-cyclists to turn to cycling if infrastructural improvements are made is also explored.

Looking forward, further research could investigate the socio-economic impacts of improved cycling infrastructure on urban mobility and public health. Such studies would enrich our understanding of the broader benefits of bicycling and support more informed policy-making. Additionally, comparative studies with other cities could provide insights into best practices that Tehran might adopt or adapt.

The remaining challenge is how effectively these findings can be integrated into a cohesive urban planning strategy that prioritizes sustainable transportation. This involves not only addressing the identified gaps but also anticipating future urban growth and mobility needs. As Jane Jacobs famously said, "Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody." This underscores the need for inclusive planning that considers the diverse needs of all city dwellers. The work done here relates to larger global efforts to combat urban congestion and pollution through sustainable transportation solutions. By demonstrating

specific needs and benefits within Tehran, this study contributes to the growing body of knowledge that supports the shift towards more livable and sustainable urban environments worldwide.

For advancing Tehran's cycling infrastructure, this study recommends the development of comprehensive cycling plans that include expanding interconnected bicycle paths, enhanced safety measures, and public awareness campaigns to foster a cycling culture. By aligning these improvements with broader urban development goals, Tehran can enhance its livability and environmental sustainability. This study not only highlights the current limitations within Tehran's bicycle infrastructure but also outlines a path for significant improvement. The alignment of this research with global sustainability goals reinforces the importance of our findings and suggests a scalable model for other cities facing similar challenges. As we have shown, the journey towards sustainable urban mobility is not just about creating paths but about connecting people to their cities in healthier, more sustainable ways.

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Application of Municipal Sewage Sludge Ash for Waste-activated Sludge Thickening and Dewatering: a Comparative Study

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ABSTRACT

In this study, the feasibility and efficiency of using sewage sludge ash (SSA) as a conditioner for waste-activated sludge and anaerobic stabilized sludge thickening and dewatering was investigated in a lab-scale. Also, the employing of SSA as an alternative coagulant along with organic and inorganic conditioners was evaluated based on the results of lab-scale tests. In this regard, the main factors effectiveness, including the sludge pH value and the injection dosage of conditioner on indices such as sludge volume index (SVI), time to filter (TTF), and specific resistance to filtration (SRF) were surveyed. Based on the results, the highest rate of SRF decrement and TTF reduction occurred at the pH value of 3 and SSA dosage of 0.25 g/g DS for waste-activated sludge. While, SSA did not have an acceptable effect on anaerobic stabilized sludge dewatering. Nevertheless, the obtained results from the review of SVI index indicated the poor and inappropriate performance of SSA for waste-activated sludge thickening. The findings of simultaneous application of SSA with cationic poly-electrolyte showed no significant improvement in the dewatering efficiency, while the usage of SSA along with ferric chloride indicated that SSA is a suitable alternative for lime in combination with ferric chloride. Finally, it can be concluded that sewage sludge ash has a potential to ameliorate the waste-activated sludge dewatering alone or as an effective alternative coagulant instead of lime besides ferric chloride, resulting in a reduction of the chemicals consumption.

Keywords: Sludge treatment, Waste-activated sludge thickening and dewatering, Conditioning, Sewage sludge ash

17. INTRODUCTION

Wastewater treatment plants (WWTPs) employing activated sludge processes are widely used and lead to the production of a large amount of waste-activated sludge (WAS), resulting in the creation of threats to the environment and human health [1,2]. The excessive growth of WAS has made it one of the most important and critical environmental issues [3]. Therefore, sludge management is one of the strategic goals in the wastewater treatment projects [4].

Among the problems that several wastewater treatment plants are facing today is the sludge disposal after stabilization and dewatering. Generally, there is not enough land for disposing of the sludge around the WWTPs, and the cost of sludge transportation is also very high [5]. In cases where the final sludge disposal locations are far away from WWTP, it is very important to reduce the volume and the weight of the sludge [6].

On the other hand, in order to decline the significant costs of treatment plant operating, as well as to prevent environmental pollution, it is essential to decrease the amount of sludge produced in wastewater treatment plants. To achieve this goal, sludge thickening and dewatering processes are used in WWTPs. In this regard, one of the important steps is the sludge conditioning, since the sludge thickening and dewatering can be performed more easily [7]. Sludge conditioning can be done in a variety of ways, such as chemical, mechanical, thermal, and combined methods [8-11].

The chemical conditioning involves the flocculation of solids and the release of absorbed water. The local cost of any required chemical conditioner, such as sulfuric acid, alum, ferric chloride, ferrous sulfate with or without lime, is a determining factor in choosing the proper option. In the past years, the cost of providing ferric chloride has decreased significantly, and this object has led to the expansion of its application individually or combined with lime in wastewater treatment plants [12-15]. The use of poly-electrolytes as coagulant or coagulant aid is also expanding. These materials are found in three forms, anionic, cationic and nonionic. Anionic poly-electrolyte is employed as a coagulant aid along with coagulants such as aluminum and iron. While cationic poly-electrolyte can be used as a primary coagulant alone or combined with coagulants such as aluminum sulfate [12,14,16].

Another method, which significantly decreases the sludge volume and weight, is the thermal drying and the incineration. The incineration can reduce the amount of sludge volume by more than 90% [17]. Many studies have already been carried out for the production of building materials using the sewage sludge ash (SSA), especially cement [18-20]. Further studies have been conducted on the phosphorous recovery from SSA [21-23].

The purpose of this study was to provide an innovative and economical solution for sewage sludge reuse. Therefore, the incineration of sewage sludge and employing the residual ash for the waste activated sludge and anaerobic stabilized sludge thickening and dewatering was investigated. As well as, the simultaneous use of the sewage sludge ash along with organic and inorganic coagulants for sludge conditioning and dewatering was evaluated with the aim of a comparative investigation. In this regard, the indices such as sludge volume index (SVI), time to filter (TTF), and specific resistance to filtration (SRF) have been considered in order to evaluate the performance of each proposed conditioner (SSA, cationic poly-electrolyte, ferric chloride, and lime) and their influences on the ability of water separation from sludge.

2. Material and methods

2.1. Sewage sludge ash (SSA) preparation

SSA was prepared by incinerating the stabilized and dewatered sludge of the municipal wastewater treatment plant (conventional activated sludge process) which is located in the south of Tehran, Iran. In this plant, the sludge is first stabilized by anaerobic digesters and then is conditioned employing cationic poly-electrolyte for dewatering. The stabilized sludge contains 58-62% volatile solids. The wet sludge cake is then dewatered using belt filter press (BFP) devices. In order to incinerate the stabilized and dewatered sludge and prepare the ash, the heat from a flare was directly contacted with the sludge in a steel enclosure. The contacted hot air temperature was 900 to 1000 °C. The sewage sludge ash was obtained after 20 minutes hot air contact duration. The results of SSA chemical analysis using the X-ray fluorescence (XRF-SPECTRO) is presented in Table 1.

Table 1. SSA composition based on the weight percentage of oxides.

Matter	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	TiO ₂	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
SSA	24.5	4.9	3.6	0.67	30.4	4.75	2.36	1.54	0.31	22.6	4.36

2.2. Sludge procurement

Daily sampling from returned activated sludge (RAS) has been performed, and thickening and dewatering experiments have been carried out. In addition, anaerobic stabilized sludge samples were investigated to verify the water separation capability. The characteristics of waste-activated sludge and anaerobic stabilized mixed sludge (primary and secondary sludge) are presented in Tables 2 and 3, respectively.

Table 2. The characteristics of the waste-activated sludge samples.

Parameter	Unit	Value
pH	...	7.03±0.20
Temperature	°C	18.2±4.0
Chemical oxygen demand (COD)	mg/L	9520±2000
Soluble chemical oxygen demand (SCOD)	mg/L	50±20
Volatile suspended solids (VSS)	mg/L	5183±1000
Volatile solids (VS)	mg/L	5700±1000
Total suspended solids (TSS)	mg/L	7595±1000
Total solids (TS)	mg/L	8350±1000
VS/TS	...	0.75±0.05
Time to filter (TTF)	s	240±60
Specific resistance to filtration (SRF)	m/kg	(6.77±0.50)×10 ⁹

Table 3. The characteristics of the anaerobic stabilized sludge samples.

Parameter	Unit	Value
pH	...	6.83±0.20
Chemical oxygen demand (COD)	g/L	22.5±3.0
Soluble chemical oxygen demand (SCOD)	mg/L	1352±100
Volatile solids (VS)	g/L	13.75±0.50
Dry solids (DS)	g/L	23.31±0.50
VS/DS	...	0.59±0.04
Water content	%	97.6±0.1

Bound water	g/g DS	4.7±0.2
Time to filter (TTF)	s	369±20
Specific resistance to filtration (SRF)	m/kg	(245±10)×10 ¹²

2.3. Sampling and analysis

In order to investigate the effect of sludge conditioning methods on the sludge thickening and dewatering processes, the pH value of the sludge samples was adjusted at the desired range employing concentrated sulfuric acid and sodium hydroxide (Merck), and its value was measured by device (JENWAY: 3510). In the next step, the conditioners including sewage sludge ash, cationic polyelectrolyte called zetag (BASF Co.), ferric chloride (SRL India) and lime (Sinato Co.) with the desired dosages, either individually or combined, were added to the sludge samples, and then mixing was conducted. In this way, the sludge and the conditioner were mixed for 5 minutes by a magnetic stirrer. Thereafter, the tests including sludge volume index (SVI), time to filter (TTF) and the specific resistance to filtration (SRF) were performed on the prepared samples.

The experiments were accomplished on sludge samples with filter paper (Whatman: #1) and Buchner funnel (Philip Harris) to measure TTF according to the standard methods for the examination of water and wastewater (APHA, 2012: section 2710H) [24] and to determine SRF based on the propounded method by Li et al., (2016) [25]. The sections including 2540, 5220D, and 2710D of the APHA, (2012) were also applied to measure solids (TS, TSS, VS, and VSS), COD and SVI, respectively. All tests were carried out with three repetitions and the average value of the results were propounded [24]. In order to make a comparison between different conditioning methods, all of the samples were evaluated against a control sample. The control sample is a raw sludge sample, which determination of its water separation capability was done without conditioning.

In the case of SSA usage as an alternative coagulant along with cationic poly-electrolyte, these two substances were simultaneously injected into the sludge, whereas in the case of SSA application besides ferric chloride, the inorganic conditioner was first infused into the sludge, and after 5 minutes of mixing, SSA was added and the mixing process was continued.

3. Results and discussion

3.1. Effect of SSA dosage and sludge pH value on WAS dewatering

In this study, two parameters of SSA dosage and sludge pH value were considered as effectual factors on the water separation ability of sludge. In this regard, the effect of SSA dosage change and sludge pH value variation on SRF measure of thickened WAS are illustrated in Fig. 1. It is clear that SRF reduction means sludge dewatering improvement. As shown in Fig. 1, at the sludge pH value of 7, the amount of SRF was decreased from 6.77×10^9 m/kg to 5.26×10^9 m/kg, with an increment in SSA dosage from zero to 0.50 g/g DS. The highest decrement of SRF at pH value of 7 which is equal to 45%, occurred in SSA dosage of 1.00 g/g DS. However, in SSA dosages of more than 1.00 g/g DS, SRF was increased again, which can be due to the bonded water formed at the surface of the free ash particles. Free ash particles mean the grains that are not adsorbed on the sludge surface and are unattached in the environment. At the pH value of 6, with an ascent in SSA dosage, SRF was declined. In this situation, the best performance of the sludge dewatering process was observed at the SSA dosage of 0.75 g/g DS, with the SRF decrease from 6.77×10^9 m/kg to 3.84×10^9 m/kg. At pH value of 5, when the SSA dosage was zero, SRF was reduced by 17%, due to the decrement of the negative zeta potential of sludge particles [26]. At this sludge pH value, SRF was declined by 51%, with SSA dosage augmenting from zero to 0.50 g/g DS. But, enhancing SSA dosage from 0.50 g/g DS to

1.00 g/g DS did not have much influence on SRF reducing. Also, SSA injection by more than 1.00 g/g DS, led to an increase in SRF value for which the reasons are mentioned. At pH value of 4 and SSA dosage of zero, the amount of SRF was decreased by 48%, which is due to the diminution of the negative zeta potential of sludge particles. But, by increasing the SSA concentration from zero to 0.25 g/g DS, the maximum reduction measure of SRF was 58%. At sludge pH value of 3, the greatest decrement of SRF was found at the lowest SSA dosage. By applying the pH value of 3 and SSA dosage of 0.25 g/g DS, the reduction rate of SRF was 67%, that 51% of which is due to the acidification of the environment and the rest is due to the SSA application.

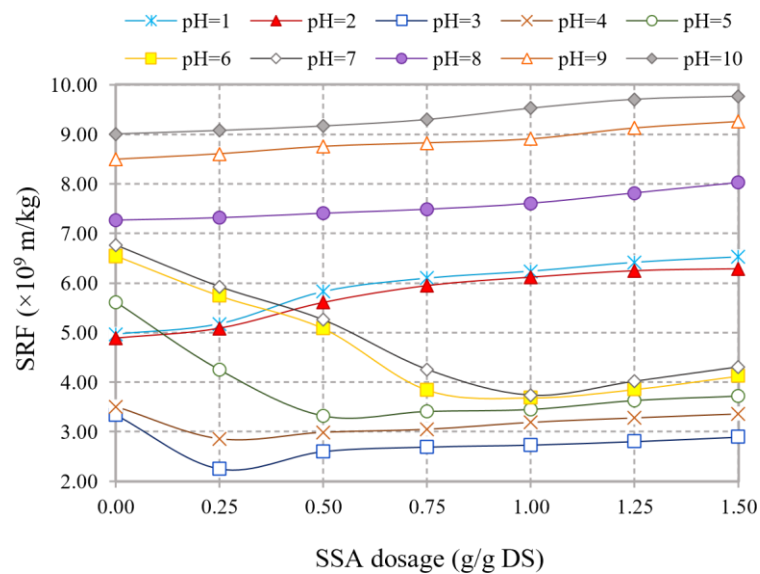


Fig. 1. Effect of SSA dosage change and pH value variation on SRF test results regarding thickened waste-activated sludge.

By decreasing the sludge pH value to less than 3 (pH=1 and pH=2), the reduction measure of SRF was declined. At these pH values, the generated fine particles from sludge flocs destructing reduce the efficiency of the dewatering process [27]. In other words, it is true that pH value diminution and acidification improve the dewatering efficiency, but at pH values of less than 3, fine particles are formed due to the demolition of sludge flocs and negatively affect the performance of the dewatering process. Due to the reduction of pH value to 2 and less than 2, SRF decrement was 28%. By enhancing SSA dosage from zero to 0.25 g/g DS, not only the efficiency of the dewatering process did not improve, but also the percentage of SRF reduction was decreased (25%). At pH values of 1 and 2, SSA dosage augmenting to more than 0.25 g/g DS led to a decrease in the sludge dewatering efficiency. The reason for this is the lack of ash particles adsorption at the sludge surface. In very acidic conditions, extracellular polymeric substances (EPS) layers around the sludge particles are destroyed [28] and virtually ash particles, which must affect these layers, are useless. As a result, the ash particles act as fine and colloidal grains and react with water molecules, which can worsen the sludge dewatering conditions.

The effects of the alkaline environment on sludge dewatering was also investigated. At pH value of 8,

SRF was enhanced by 8%, which is due to an increase in the negative zeta potential of sludge particles [2]. It was also found that by increasing SSA dosage, SRF value was enhanced and sludge dewatering became worse. The same trend was observed for pH=9 and pH=10. It can be said that, on the one hand, the creation of the alkaline environment and, on the other hand, augmenting SSA dosage have a negative influence on the sludge dewatering.

Generally, it can be concluded that by decreasing the sludge pH value, SSA consumption is also reduced. For example, the optimum dosage of SSA at pH=7 is 1.00 g/g DS. However, the optimal dosage of SSA at pH=3 is 0.25 g/g DS. Also, the combination of an acidic environment with SSA injection is more suitable than SSA addition individually. In order to determine the optimal operating conditions, an economic review is needed to specify and

compare the cost of SSA consumption individually or in combination with the acidic environment. If the SSA is used solely, it should be noted that the transportation cost of dewatered sludge, which weight has doubled as a result of SSA injection, is enhanced. If the option of SSA application in the acidic environment is considered, the purchasing cost of acidic substances for sludge acidifying and the supplying cost of alkaline materials for sludge neutralizing should be attended.

Another standard test to measure sludge dewatering capability is TTF. Reducing TTF means improving the dewatering process efficiency. TTF experiment was performed three times on each sludge sample that the results of which are shown in Fig. 2 in an average form. Generally, the conversion of sludge bonded water to the free water leads to a reduction in TTF [29]. The results showed that TTF had the highest reduction rate compared to the control sample, at pH value of 3 and SSA dosage of 0.25 g/g DS, in which TTF was declined from 240 s to 81 s. Also, the best performance of dewatering process in neutral pH range was observed at SSA dosage of 1.00 g/g DS. In general, the findings provided by TTF test confirm the results of SRF experiment and are consistent with it.

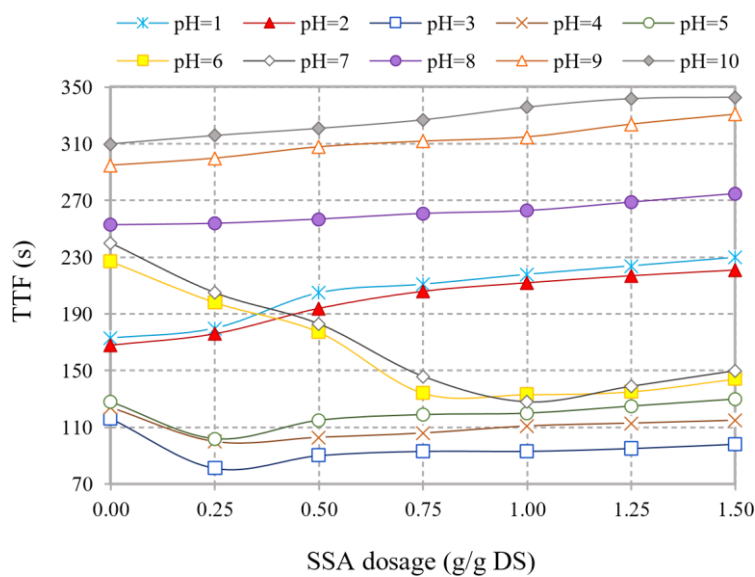


Fig. 2. Effect of SSA dosage change and pH value variation on TTF test results regarding thickened waste-activated sludge.

3.2. Effect of SSA dosage on WAS thickening

The effect of SSA dosage on the WAS thickening was investigated using SVI. As illustrated in Fig. 3, the sludge settling and thickening were generally improved by increasing SSA dosage.

SVI value of raw sludge was equal to 125 mL/g, which show a sludge with a concentration of $0.73 \pm 0.05\%$. When SSA dosage was increased, the SVI was improved. So that in the SSA dosage of 0.50 g/g DS, SVI reached 85 mL/g, indicating a sludge with a concentration of $1.20 \pm 0.05\%$. By increasing the SSA concentration to 1.00 g/g DS, SVI value attained to 49 mL/g, indicating a sludge with a density of $2.00 \pm 0.05\%$. In the sludge thickening process, the optimum dosage of SSA is 1.00 g/g DS, because the increase in this amount does not have a significant influence on SVI reducing.

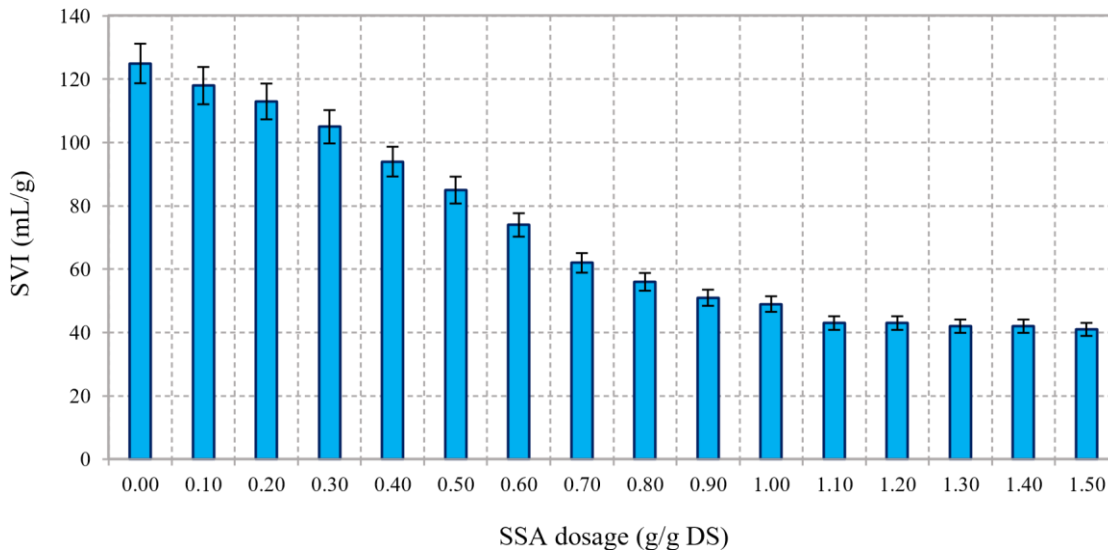


Fig. 3. Effect of SSA dosage variation on SVI test results regarding waste-activated sludge.

However, with an accurate analysis of the findings, it can be said that SSA is not an appropriate option for sludge thickening. In order to understand this issue, it is important to pay attention to this example. The waste-activated sludge sampled from WWTP in southern Tehran had a solids concentration of 7.265 g DS/L. Given that the optimum SSA dosage for sludge thickening was obtained about 1.00 g/g DS, to condense a liter of sludge, SSA should be added by 7.265 g. After adding SSA into the sludge, the solids concentration reaches 14.530 g/L, which represents a sludge with a density of approximately 1.453% at the beginning of the SVI test. The thickened sludge with a solids concentration of 2.00% is obtained after 30 minutes of the thickening process. Thus, it can be concluded that SSA increases the efficiency of sludge thickening process by only 0.547%, which indicates the weak performance of SSA in sludge thickening. Because a desirable coagulant should thicken the sludge by 3-5%.

3.3. Effect of SSA dosage on anaerobic stabilized sludge dewatering

In this stage of experiments, SSA influence on dewatering of the anaerobic stabilized sludge from WWTP in southern Tehran was evaluated that the results of which are presented in Fig. 4. It should be noted that the dewatering of an anaerobic stabilized sludge is far more difficult than a waste-activated sludge that the reasons for which are as follows [3,30]:

- (1) Commonly, an anaerobic stabilized sludge has smaller particles than a waste-activated sludge.
- (2) The negative zeta potential of anaerobic stabilized sludge particles is far more than the waste activated sludge particles.
- (3) Anaerobic stabilized sludge particles generally have a behavior close to colloidal grains due to the depletion of organic materials and the stabilization.

In Fig. 4, the effect of SSA dosage on SRF value of the anaerobic stabilized sludge can be observed. Noteworthy is the SRF value of the anaerobic stabilized sludge before SSA injecting, which was equal to 246×10^{12} m/kg. This value is far greater than the waste-activated sludge SRF (6.77×10^9 m/kg). When SSA density was increased from zero to 1.00 g/g DS, the sludge SRF was decreased by 2%. By augmenting the SSA concentration to 2.00 g/g DS, SRF was reduced by 11%. Also, at SSA density of 3.00 g/g DS, the SRF value was declined by 21%. This means that the concentration of conditioned sludge particles in comparison with the non-conditioned one has been 4 times, but the performance of the sludge dewatering process has not improved significantly. In general, the results show that SSA does not have an acceptable effect on the dewatering of an anaerobic stabilized sludge.

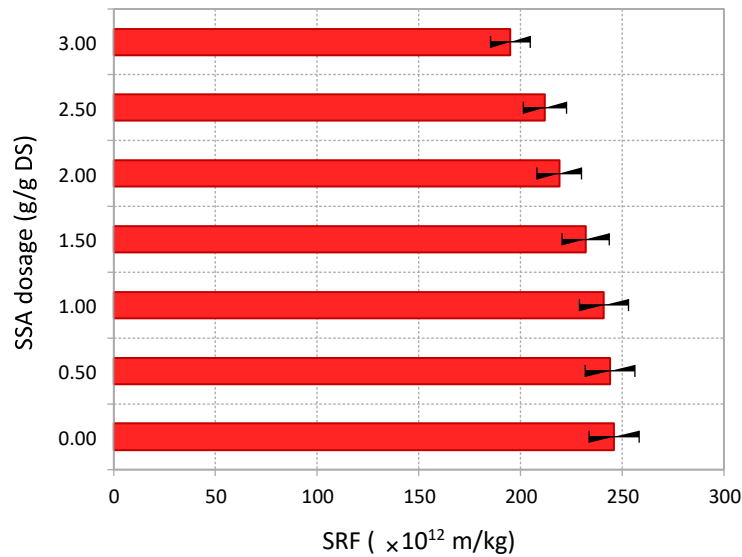


Fig. 4. Effect of SSA dosage variation on SRF test results regarding anaerobic stabilized sludge.

3.4. Application of SSA as coagulant aid along with cationic poly-electrolyte (zetag)

In this section, the influences of SSA dosage and cationic poly-electrolyte concentration on waste activated sludge SRF were investigated under the neutral pH that the results of which are illustrated in

Fig .5. The concentration of cationic poly-electrolyte for WAS conditioning was selected based on EPA [31]. The results in the normal conditions without SSA addition indicate that the highest reduction measure of SRF was achieved at the zetag concentration of 4 mg/g DS. In other words, the optimum zetag concentration for WAS dewatering is 4 mg/g DS. However, increasing the SSA dosage from 0.10 g/g DS to 0.50 g/g DS, not only did not have a positive effect on SRF reducing, but also had a negative impact on sludge dewatering.

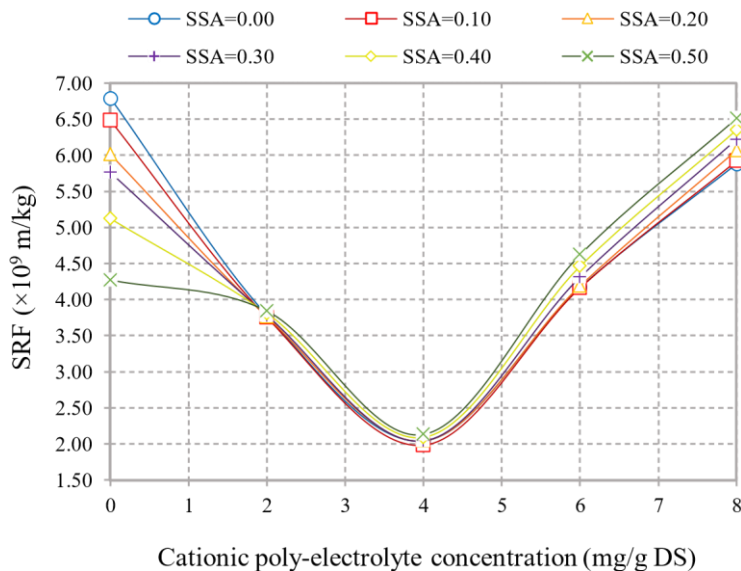


Fig. 5. Effect of SSA dosage and cationic poly-electrolyte concentration on SRF test results regarding thickened waste activated sludge.

The results of the reviews clearly show that by enhancing the SSA dosage in a constant concentration of cationic poly-electrolyte, SRF value is increased compared to the one in which the SSA injection dosage is equal to zero. The reason for the negative effect of SSA injection on sludge dewatering during concurrent usage along with cationic poly-electrolyte is probably the neutralization of the cationic polyelectrolyte surface charges by SSA particles. Positive charges in the polymer chain, which are responsible for connecting to the sludge particles and creating a bridge between them, are neutralized by SSA particles and thus, in the presence of SSA, the cationic poly-electrolyte function is reduced. Therefore, it can generally be concluded that the interaction between cationic poly-electrolyte and SSA does not improve sludge dewatering. So, SSA can't be employed as a coagulant aid along with cationic poly-electrolyte.

3.5. Application of SSA as coagulant aid along with ferric chloride

One of the traditional methods for sludge conditioning is the ferric chloride utilization with lime, which is widely employed for filter press devices. In this section, the optimal dosage of ferric chloride and lime was first specified for WAS dewatering. In the next step, the optimum dosage of ferric chloride along with SSA was also determined and then the results of these two methods were compared. As previously mentioned, in the sludge conditioning process by ferric chloride and lime, ferric chloride was first injected into the sludge, and after a concise time, lime was added. Dosages of ferric chloride and lime presented in Table 4, were selected according to EPA [31] for WAS conditioning. Based on the first column of Table 4 (from left to right), ferric chloride with dosages of zero to 100 mg/g DS was injected into the sludge. Also, the lime dosage varied from zero to 260 mg/g DS. According to the results reported in the second column of Table 4 (from left to right), when the lime dosage was equal to zero, by increasing the dosage of ferric chloride, the waste-activated sludge SRF was declined. In a ferric chloride dosage of 100 mg/g DS, the reduction rate of SRF was 57%.

Based on the results of the second to eighth columns of the aforesaid table, by enhancing the lime dosage along with augmenting the ferric chloride concentration, the SRF value was almost decreased. Therefore, the optimum dosages of ferric chloride and lime are 90 mg/g DS and 240 mg/g DS, respectively. Under such conditions, the reduction value of SRF was 71%.

Table 4. Effect of ferric chloride concentration and lime dosage on thickened waste-activated sludge SRF.

		Lime dosage (mg/g DS)						
		0	160	180	200	220	240	260
Ferric chloride dosage (mg/g DS)								
0		6.84	6.83	6.71	6.17	6.52	6.64	6.79
4.83	3.62	3.67	3.61	3.72	3.76	3.85		50
60		4.12	3.69	3.14	3.05	3.05	3.10	3.10
70		3.63	2.91	2.77	2.68	2.68	2.70	2.70
80		3.24	2.94	2.58	2.50	2.43	2.35	2.35
90		2.96	2.75	2.49	2.27	2.12	1.98	2.00
100		2.95	2.74	2.46	2.37	2.10	2.15	2.13

* The SRF values were multiplied by 10^{-9} .

* Dosages of ferric chloride and lime were selected based on EPA [31].

The influences of simultaneous application of ferric chloride and SSA on the waste-activated sludge SRF are presented in Table 5. For this purpose, ferric chloride with the dosages of zero to 100 mg/g DS was first injected into the sludge. After the reaction of ferric chloride with sludge, the SSA injection with the dosages of zero to 260 mg/g DS was performed and finally, the dewatering test was done on the conditioned sludge. The results reported in Table 5 show that, by increasing the ferric chloride concentration and SSA dosage, SRF value is reduced. It can also be said that enhancing the injection dosage of these conditioners led to a further decrease in SRF value.

Table 5. Effect of ferric chloride concentration and SSA dosage on thickened waste-activated sludge SRF.

Ferric chloride dosage (mg/g DS)		SSA dosage (mg/g DS)						
		0	160	180	200	220	240	260
0		6.89	6.41	6.33	6.25	6.14	6.08	6.01
4.90	4.67	4.45	4.21	4.03	3.94	3.89		50
60		4.11	3.98	3.76	3.53	3.42	3.39	3.34
70		3.72	3.56	3.40	3.27	3.19	3.07	2.89
80		3.29	3.03	2.81	2.51	2.23	1.92	1.89
90		3.02	2.82	2.64	2.44	2.17	1.96	1.78
100		2.98	2.73	2.45	2.23	2.02	1.83	1.62

* The SRF values were multiplied by 10^{-9} .

* Dosages of ferric chloride were selected based on EPA [31].

The optimal operating conditions in this method are achieved when the dosages of ferric chloride and SSA are equal to 80 mg/g DS and 240 mg/g DS, respectively. In other words, the reduction rates of SRF value in the methods of ferric chloride and lime usage and ferric chloride and SSA application are approximately equivalent. Considering the uniformity of the optimal operating conditions, it is possible to compare these two options. Technically and efficiently, the reduction rate of SRF value, and thus the improvement of the water separation capability from sludge, was approximately the same in both options. But, the ferric chloride dosage in the option of ferric chloride and lime usage was 11% higher than the option of ferric chloride and SSA application. So, the combination of ferric chloride and SSA reduces the chemicals consumption, which is economically important.

On the other hand, the injection dosage of SSA and lime was equal in both options. But, a significant point is the high cost of lime purchasing and transporting to the treatment plant location. This is while SSA is generated on the site of the WWTP by sludge incinerating. Hence, SSA does not require transportation and can be a suitable alternative for lime in the option of ferric chloride and lime usage, which will reduce the operating cost of WWTP.

4. Conclusion

The results of this study showed that the sludge incinerating and the reusing of produced sludge ash can be considered as an operational solution in wastewater treatment plants and lead to the operating costs reduction. Because sewage sludge ash reusing at the wastewater treatment plant site, on the one hand, decreases the supplying cost of chemicals needed for sludge conditioning process, and on the other hand, attenuates the transferring cost of sludge ash from treatment plant site to the depot location. Also, sewage sludge ash can be employed individually as a coagulant or in

combination with ferric chloride as a coagulant aid for dewatering process. But its application for sludge thickening is not recommended. In general, it can be concluded that sewage sludge ash usage has comparative advantages in the dewatering process and can be considered as an operational option in wastewater treatment plants.

Acknowledgments

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Investigation of the Properties of Masonry Mortar Containing Recycled Aggregate and Zeolite with a Focus on Sustainable Development and Green Mortar

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ABSTRACT

In this article, the characteristics of masonry mortar made with recycled sand and zeolite are investigated in the context of sustainable development. For this purpose, 8 masonry mortar mix designs were considered, in which, in addition to the base design, recycled sand replaced natural sand by 50% and 100%, and zeolite replaced cement by 10%, 15%, and 25%. Additionally, the water-to-cement weight ratio was set at 0.55, and the cement-to-sand weight ratio was set at 1:3. Experiments were designed to measure various physical and mechanical properties of the masonry mortar made with recycled sand and zeolite. Tests for water absorption and density were conducted to evaluate physical properties, as well as tests for compressive strength and flexural strength to assess mechanical properties, and a flow table test to evaluate workability and efficiency. The tests performed on the masonry mortars made with recycled sand and zeolite have yielded acceptable results that meet the requirements of the national standard for masonry mortar. They demonstrate that replacing 50% of natural sand with recycled sand and 15% of cement with zeolite can be a good strategy for reducing the use of natural materials, promoting sustainable development, and achieving green mortar.

Keywords: Recycled Sand, Zeolite, Sustainable Development, Green Mortar, Masonry Mortar

1. INTRODUCTION

Cement is one of the most fundamental components of concrete and mortar, which is why it is produced in significant volumes worldwide. A report published by the United States Geological Survey in 2010 stated that approximately 2 billion tons of Portland cement were produced globally in 2010, leading to the production of 12 to 14 billion tons of concrete and masonry mortar. On the other hand, cement production is associated with numerous environmental issues; therefore, it is essential to address them appropriately to reduce the environmental degradation caused by its unrestrained production. The cement production process consumes a great deal of energy, to the extent that the production of cement clinker occurs at temperatures close to 1450 degrees Celsius. Cement factories, after power plants, are the second-largest producers of greenhouse gases such as carbon dioxide [1]. Generally, the production of one ton of cement results in the production of one ton of carbon dioxide, and the cement industry accounts for 9% of the total carbon dioxide emissions globally; hence, the biggest concern regarding environmental issues in cement production is to reduce the greenhouse gases produced in this process as much as possible. One of the global efforts to reduce environmental pollution caused by cement production is the use of alternative materials to cement [2].

One suitable alternative to cement can be natural zeolite, a hydrated aluminosilicate of alkaline and alkaline earth cations, which has been widely used in constructions since ancient times [3]. However, its application as a popular type of natural pozzolan in the production of pozzolanic cements began in the early twentieth century and has shown a growing trend since then. Zeolite contains a significant amount of active SiO_2 and Al_2O_3 , which chemically combine with calcium hydroxide produced by cement hydration to form C-S-H gel and additional aluminates, thereby improving the hardened cement's microstructure. Research on zeolite-containing concretes has demonstrated an increase in the strength of these concretes. The use of zeolite as a pozzolanic additive with a high absorption percentage (close to 40% of its weight) creates internal curing in concrete, resulting in low permeability and high durability at a low water-to-cement ratio. Moreover, zeolite-containing concretes exhibit much better environmental performance compared to cement, such that replacing 20% of cement with zeolite can reduce the concrete's global warming index by up to 70% [4]. This justifies the use of zeolite from a sustainable development perspective.

In recent years, due to the increasing use of natural materials and resources in construction and the rising demand for concrete, access to natural aggregate materials has become more difficult. On the other hand, with the demolition of old structures, the need for disposal sites for construction debris has significantly increased, leading to environmental pollution and the occupation of suburban areas with construction debris. In many countries, due to the filling up of surrounding urban spaces and the lack of suitable sites for the burial of construction debris, construction waste has become a fundamental problem [5]. Additionally, the natural resources required for new construction are becoming scarcer day by day, and accessing them is becoming more challenging. An appropriate and sustainable development-based solution is the use of construction waste for new construction, which can alleviate the need for natural materials and reduce pollution caused by the burial of construction waste. In this regard, extensive research has been conducted in recent years, and many countries have developed regulations and guidelines for concrete recycling and use in construction and masonry [6].

From an environmental perspective, the use of recycled fine aggregate as sand and gravel can have several advantages, including: (1) reducing the extraction of sand and gravel, which has significant environmental impacts worldwide; (2) reducing energy consumption and carbon dioxide emissions; and (3) preventing the illegal disposal of recycled material fractions.

Researchers are increasingly focusing on innovation in green concrete and their environmental performance throughout their lifecycle. While recycled aggregate concrete is a type of green concrete, researchers have endeavored to explore strategies to make it greener. Various types of waste or leftover materials are employed in the composition of recycled aggregate concrete, and the number of lifecycle assessment studies has increased over the past decade [7]. This research investigates the physical and mechanical properties of recycled aggregate concrete made with recycled sand and zeolite as alternative materials to cement, which is widely used in civil engineering works. Utilizing recycled materials in this field can save valuable natural resources and allow for the use of natural materials in more sensitive areas that require high-quality and consistent materials. Moreover, it reduces the need for vast areas of land around cities for the disposal of construction debris, which is currently becoming a major issue in large cities. Additionally, in sustainable development studies, the replacement of cement with zeolite leads to a reduction in energy consumption and greenhouse gas emissions (global warming index). In previous studies, some characteristics of recycled sand and zeolite, such as particle size distribution, have varied, which can significantly affect the properties and characteristics of the resulting mortars. Therefore, to reduce the variables affecting the test results, uniform particle size distribution was used for both natural and recycled sand in the present study. Furthermore, the performance of all masonry mortars was limited within a specific range, and to prevent the effects of moisture changes in materials, saturated surface dry aggregates were used.

2. Materials and Mixing Design

2.1. Characteristics of Materials

In this research project, Type 2 Portland cement obtained from the Tehran Cement Factory has been utilized. This type of cement is suitable for applications requiring moderate heat of hydration and resistance to sulfates. The natural sand used in this study is of river origin with a maximum particle size of 4.75 millimeters. Recycled sand is obtained from the crushing of existing concretes in locations designated for the disposal of construction debris and, after sieving, is brought to the required sizes. Table 1 presents the characteristics of the concrete containing recycled sand.

Table 1. Characteristics of natural aggregate materials

Characteristics	Value
Water/Cement	340.
Cement (kg/m3)	420
Water (kg/m3)	8/142
5.9 mm (kg/m3) - 19 Aggregate	335
Aggregate 4.75 - 12.5 mm (kg/m3)	258

Table 2 provides the technical specifications of the aggregates used. Investigations have shown that the water absorption of recycled sand is significantly higher than that of natural sand, which may be attributed to the different physical and chemical properties of recycled sand. Recycled sands typically have more diverse absorption surfaces, possibly due to the presence of various surfaces with different absorption properties. Additionally, the apparent density of recycled sand is lower than that of natural sand, which may be primarily due to the presence of hydrated cement particles attached to the surfaces of recycled sand.

Table 2. Characteristics of recycled aggregate fines

Characteristic	Water Absorption (%)	Density (Ton/m ³)
Coarse Aggregate	41.3	51.2
Fine Aggregate	39.12	28/2

The zeolite used in this study is sourced from a production facility located in Semnan. Table 3 presents the chemical analysis results of Portland cement and zeolite, while Table 4 lists the compositions present in the recycled sand used.

Table 3. Chemical composition analysis of used materials

Chemical Composition (%)	Cement	Zeolite
SiO ₂ (%)	27.30	64.9
Al ₂ O ₃ (%)	4.60	12.3
Fe ₂ O ₃ (%)	2.70	0.36
CaO (%)	46.70	0.1
MgO (%)	3.50	0.9

SO₃ (%)	2.04	0.79
Na₂O (%)	0.34	
K₂O (%)	0.52	
Equivalent Alkali (%)	0.68	
LOI (%)	4.84	4.18

Table 4. Constituents of recycled sand

Component	Weight Percentage (%)
Concrete and Cement	94.32
Clinker and Brick Particles	2.27
Other Mineral Materials	2.04
Asphalt	0.76
Ceramic Materials	0.34
Other Materials	0.27

The fine aggregate used in this project was obtained from the aggregate sources, and the particle size distribution of it was determined according to ASTM C144 standards [8]. The particle size distribution of recycled fine aggregate was analyzed separately, and based on the desired grading, the particle size distribution was adjusted accordingly. The fine aggregate was divided into several size ranges, including 0-0.5, 0.5-0.150, 0.150-0.300, 0.300-0.630, 0.630-1.180, 1.180-2.360, and 2.360-4.750, and then mixed with each other in specified weight proportions to meet the particle size distribution requirements specified in ASTM C144 standard. Prior to the adjustment of particle size distribution, natural sand was coarser, and recycled sand was finer. After the adjustment of particle size distribution, they both fell within the acceptable range of the standard. Figure 1 illustrates the changes in particle size distribution.

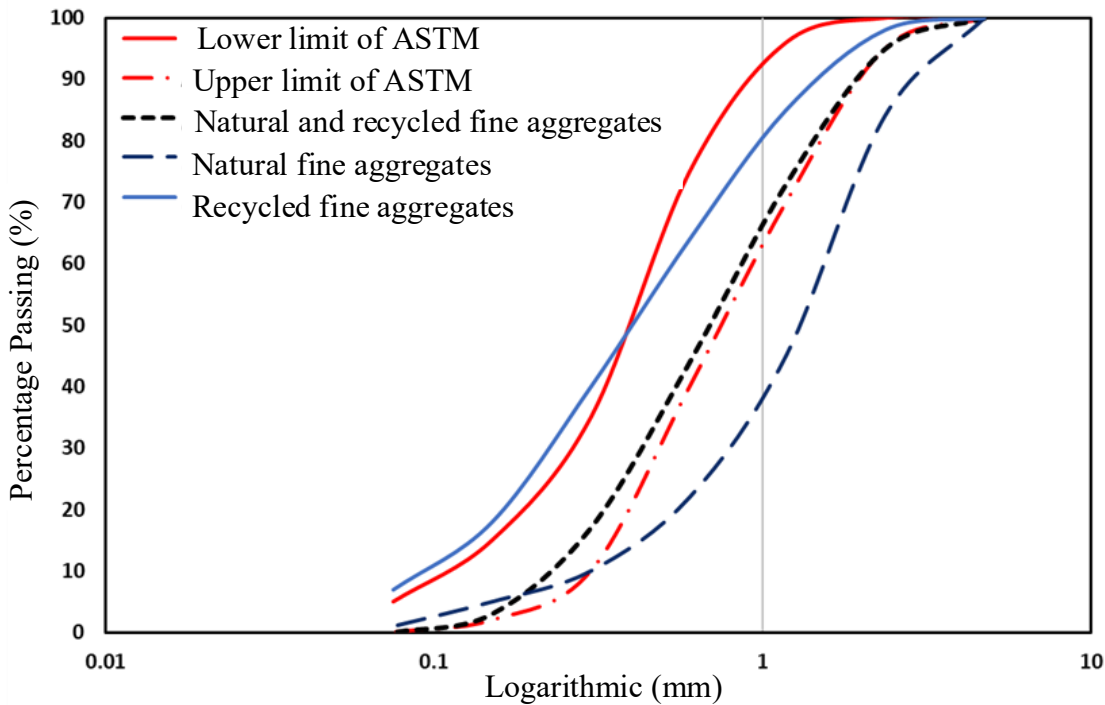


Fig. 1. Particle Size Distribution Analysis of Fine Aggregate from Natural and Recycled Sources within ASTM C 144 Grading Ranges

2.2. Mixing Design

In this study, one reference sample without using zeolite and recycled aggregates and seven different samples using zeolite as a substitute for cement and recycled aggregates instead of natural aggregates have been considered (Table 5). These samples were prepared with different percentages of zeolite substitution at 10%, 15%, and 25%, and recycled aggregates at 50% and 100%. Based on the results of the flow table test, the water-to-cement ratio for the reference sample was determined to be 0.55. In this sample, the ratio of cementitious materials to sand was considered as 1:3. Due to the high water absorption percentage by recycled aggregates and the possibility of error in preparing mortar mixtures, both types of sand were saturated with a dry surface in this study. For this purpose, the required amount of sand for each sample was saturated in water 24 hours before, and two hours before preparing the samples, natural and recycled sands were brought to a state of saturation with a dry surface using heating devices such as a hairdryer, as well as by shaking. The mixing process was carried out at a temperature of 25 ± 2 degrees Celsius. Finally, the samples were removed from the molds after 24 ± 2 hours and placed in a water and lime solution for curing.

Table 5. Prepared Mixing Designs

Mixing Design	NM	10Z M	RM -50	RM- 100	10ZRM -50	10ZRM -100	15ZRM -50	25ZRM -50
Cement (kg/m ³)	450	405	450	450	405	405	382.5	382.5
Zeolite (kg/m ³)	0	45	0	0	45	45	67.5	112.5
Water (kg/m ³)	274.5	274.5	274.5	274.5	274.5	274.5	274.5	274.5
Water/Cement	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Saturated Natural Fine Aggregate (kg/m3)	135	1350	675	0	675	0	675	675
	0							
Saturated Recycled Fine Aggregate (kg/m3)	0	0	675	135	675	1350	675	675
				0				

2.3. Research Method and Mortar Testing

The mortar tests are conducted in both fresh and hardened states. Below is a summary of the designed experiments for the research:

2.3.1 Mixing Design

The bulk density of mortars is measured according to standard EN 1015-6 [9].

2.3.2 Properties of Hardened Mortar

In this study, the compressive and flexural strength of concrete specimens that have hardened are assessed according to standard EN 1015-11 [10, 11] at ages 7 and 28. The water absorption coefficient test is also conducted as follows: initially, the specimens are kept in water at a temperature of $25\pm 2^{\circ}\text{C}$ for 24 hours, then the weight in the saturated surface-dry state is measured, and finally, they are dried at a temperature of $110\pm 5^{\circ}\text{C}$ to measure their dry weight. The bulk density of mortars is measured using standard EN 1015-10 [9]. The dimensions and number of specimens used in the experiment are presented in Table 6.

Table 6. Number and dimensions of test specimens

Test	Number of Test Specimens	Dimensions of Specimen
Water Absorption	3	mm40 * 40 * 160
Bulk Density	3	mm40 * 40 * 160
Flexural Strength	3	40 * 40 mm
Compressive Strength	6	mm40 * 40

3.Results and Discussion

3.1.Workability and Setting Time of Fresh Mortar

The workability values for the base sample and mixtures with 50% and 100% replacement of natural aggregate with recycled aggregate were obtained as 178, 172, and 163 millimeters, respectively. The analysis of the results indicates that despite considering a constant water-to-cement ratio and the use of saturated surface-dry recycled sand, the workability of fresh mortar decreases with increasing replacement ratio of natural sand with recycled sand. Substituting 50% of natural sand with recycled sand does not show a significant change in the workability of fresh mortar, but with more than 50% replacement, the workability of fresh mortar starts to decrease more rapidly. Among the reasons for the decrease in workability in mortar made with recycled sand, mention can be made of its more angular shape and greater surface roughness compared to natural sand. For instance, in the case of 100% recycled sand, the workability of fresh mortar decreases by 24.8%. These results are presented in Figure 2a.

Furthermore, in the case of substituting 10% zeolite in mixtures with 0%, 50%, and 100% recycled aggregate, the workability values were obtained as 178, 176, and 170 millimeters, respectively. In the mixture with 100% recycled aggregate, the workability of fresh mortar decreases by 49.4%. These values indicate a lower reduction compared to mixtures solely with recycled aggregate. These results are observable in Figure 2b. Additionally, considering the flow table values for zeolite replacement percentages ranging from 0% to a specific value (10% to 25%) alongside a constant 50% recycled aggregate and other concrete constituents, the workability initially increases and then decreases

with increasing zeolite replacement. These results are scrutinizable in Figure 2c. Moreover, Table 7 provides the workability values for all mixtures.

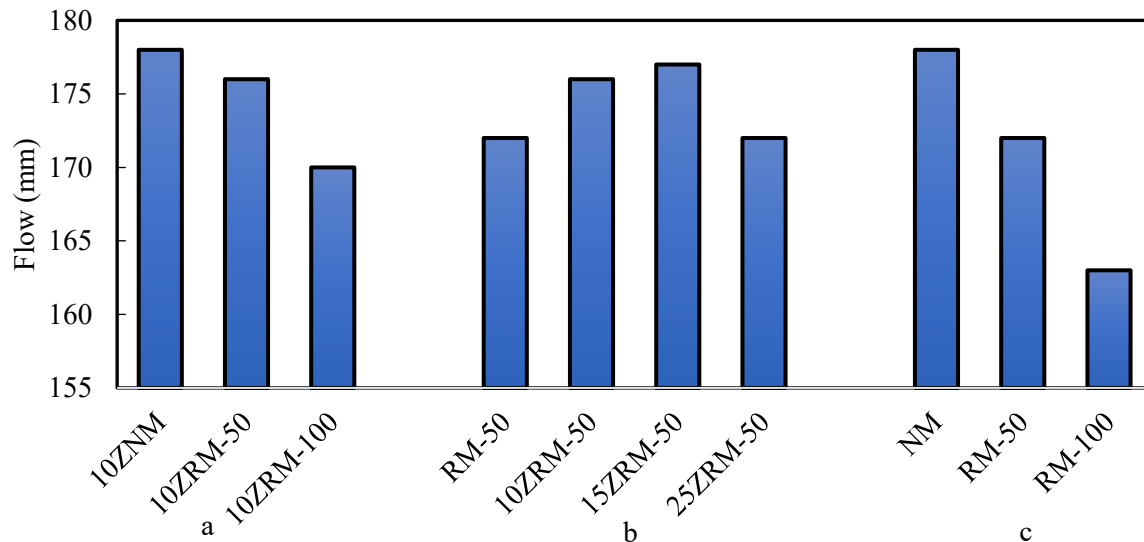


Fig. 2. Comparison of flow values with increasing substitution levels: (a) Recycled sand in zeolite-containing design, (b) Zeolite in designs with equal amounts of natural and recycled sand, (c) Recycled sand in the base design

One of the essential components for mortar is its setting time. Setting time indicates how long a mortar can be used in construction works with a reasonable amount of energy expenditure. Naturally, as time passes, the setting time decreases. According to the standard definition, setting time is defined as the time it takes for the workability of fresh mortar to decrease by 30 millimeters compared to the initial workability measurement taken 10 minutes after the start of mixing.

The setting time for the base sample made with natural sand and with 50% and 100% replacement rates of recycled aggregate was calculated as 22.52 and 17.21 minutes, respectively. It can be observed that with a 50% increase in the replacement rate of recycled aggregate with natural sand, there is a decrease of approximately 23% in the setting time. These results are depicted in Figure 3a. Additionally, in the case of substituting 10% zeolite in mixtures with 0%, 50%, and 100% recycled aggregate, the setting time values were obtained as 21.5, 18.2, and 14.1 minutes, respectively. In the mixture with 100% recycled aggregate, the setting time of fresh mortar decreases by 34.42%. These values indicate a lower reduction compared to mixtures solely with recycled aggregate. These results are observable in Figure 3b. Furthermore, considering the flow table values for zeolite replacement percentages ranging from 0% to a specific value (10% to 25%) alongside a constant 50% recycled aggregate and other concrete constituents, a decreasing trend in setting time is observed again. These results are scrutinizable in Figure 3c. Additionally, Table 7 provides the setting time values for all mixtures.

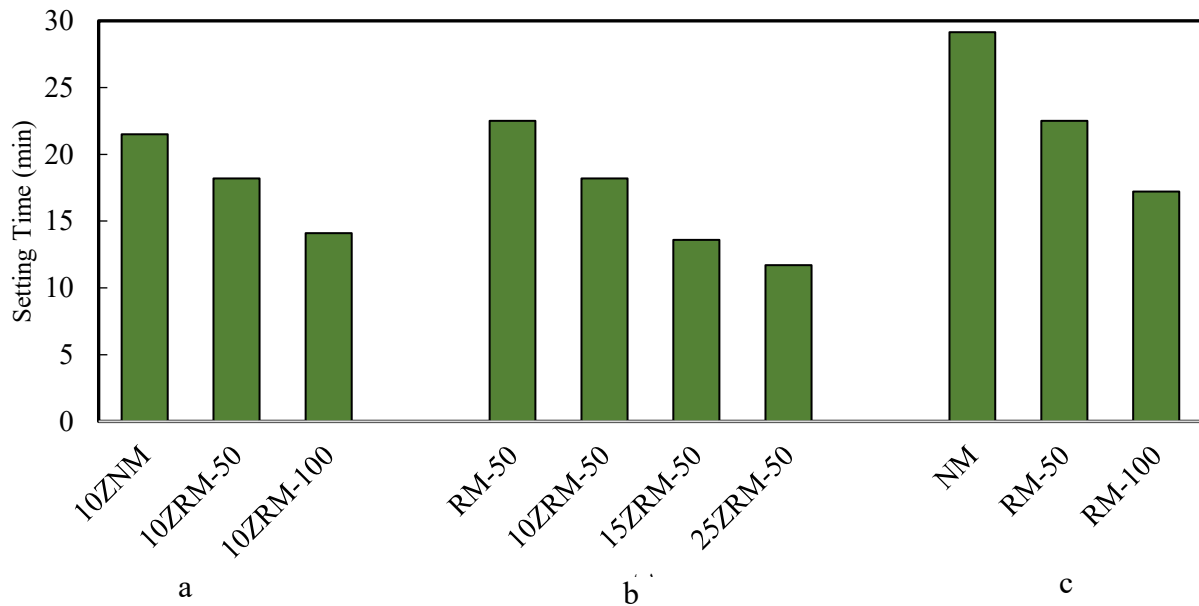


Fig. 3. Comparison of flow values with increasing substitution levels: (a) Recycled sand in zeolite-containing design, (b) Zeolite in designs with equal amounts of natural and recycled sand, (c) Recycled sand in the base design

Table 7. Results of tests related to fresh and hardened mortar

Test	Fresh Mortar Bulk Density (Ton/m ³)	Hardened Mortar Bulk Density (Ton/m ³)	Water Absorption (%)	Flow of Fresh Mortar (mm)	Setting Time of Fresh Mortar (min)
NM	2.11	2.12	6.96	178	29.14
10ZNM	2.12	2.15	6.36	178	21.5
RM-50	1.91	2.03	8.46	172	22.52
RM-100	1.84	1.89	9.36	163	17.21
10ZRM-50	1.93	1.97	8.17	176	18.2
10ZRM-100	1.83	1.94	7.02	170	14.1
15ZRM-50	1.95	2.02	8.79	177	13.6
25ZRM-50	1.95	1.98	8.15	172	11.7

3.2. Bulk Density of Fresh and Hardened Mortar

In this study, the bulk density of freshly prepared mortar made with natural sand and replacement percentages of 0%, 50%, and 100% with recycled aggregate was calculated as 2.11, 1.91, and 1.84 Ton/m³, respectively. Additionally, the bulk density of hardened mortar was calculated for mixtures made with natural sand and replacement percentages

of 0%, 50%, and 100% with recycled aggregate as 2.12, 2.03, and 1.89 Ton/m³, respectively. The investigation of experimental results demonstrates that overall, with an increase in the replacement ratio of natural sand with recycled aggregate, both the bulk density of fresh and hardened mortar decreases. One of the reasons for the decrease in bulk density in mortars made with recycled aggregate is the higher porosity of recycled aggregate compared to natural sand. Moreover, the sharp-edged nature and rough surface of recycled aggregate result in an increase in entrapped air within the mortar, consequently leading to a decrease in bulk density. Additionally, it can be found from the extracted results that an increase in zeolite substitution in the bulk density of both fresh and hardened mortar has little effect, which can be attributed to the close density of cement to zeolite, as each amount of cement has been replaced by the same amount of zeolite. The results of this section are presented in Table 7.

3.3. Water Absorption Percentage of Hardened Mortar

The water absorption percentage of hardened mortar was measured for the base sample and replacement percentages of natural sand with recycled aggregate at 0%, 50%, and 100% as 96.6%, 46.8%, and 36.9%, respectively. Considering the significant difference in water absorption coefficients between natural sand (41.3%) and recycled aggregate (39.12%), the results obtained in this experiment confirm this. The examination of results indicates that at a replacement percentage of 100%, water absorption increases by 4.2%.

The water absorption percentage of hardened mortar was measured for samples with equal amounts of natural and recycled sand and replacement percentages of zeolite at 0%, 10%, 15%, and 25%, yielding 46.8%, 17.8%, 49.8%, and 15.8%, respectively. The analysis of results shows that zeolite substitution has little effect on the water absorption percentage of hardened mortar. The results of this section are provided in Table 7.

3.4. Compressive Strength

Compressive strength testing was conducted on specimens broken in the flexural strength test. The compressive strength of the 7-day base sample made with natural sand was estimated at 18.24 MPa, and with an increase in the percentage of natural sand replacement with recycled sand to 50% and 100%, the compressive strength reached 14.56 MPa and 12.08 MPa, respectively, indicating a 20% and 33% reduction in compressive strength, respectively. Therefore, an increase in the amount of recycled aggregate correlates directly with a decrease in compressive strength. Consequently, on average, for each 10% replacement of natural sand with recycled sand, a 3.3% decrease in compressive strength of the 7-day sample is observed. The compressive strength of the 28-day base sample made with natural sand was estimated at 28.83 MPa, and with an increase in the percentage of natural sand replacement with recycled sand to 50% and 100%, the compressive strength reached 26.99 MPa and 22.39 MPa, respectively, indicating a 6.4% and 22.3% reduction in compressive strength, respectively (Figure 4a). Therefore, increasing the amount of recycled aggregate correlates directly with a decrease in strength. By comparing the strength reduction between the 7-day and 28-day samples, it can be observed that the decrease in strength is greater for the 7-day samples than for the 28-day samples.

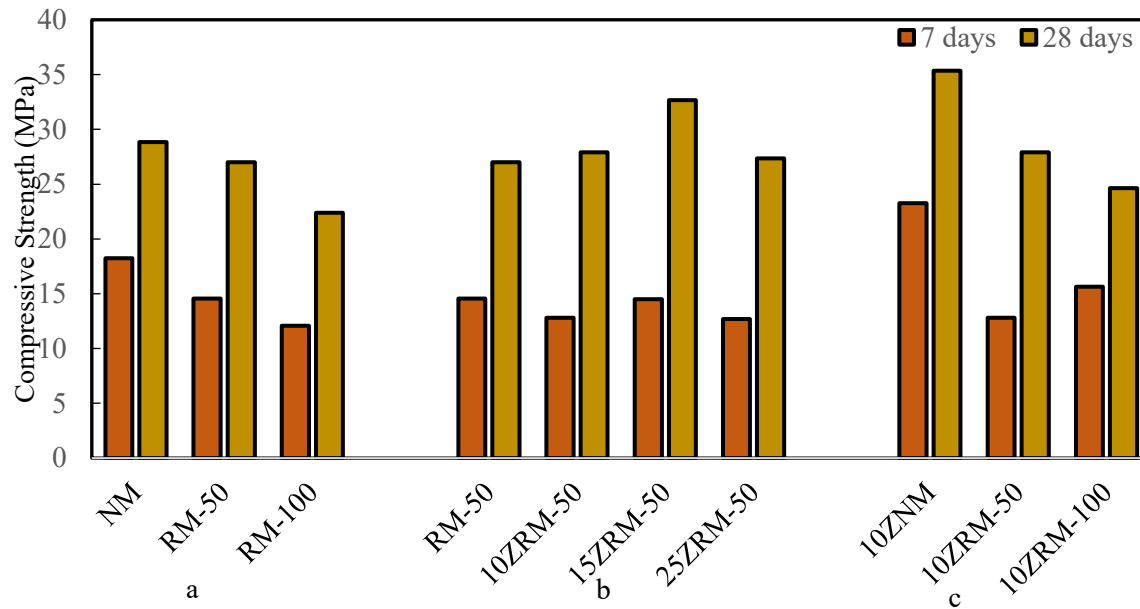


Fig. 4. Compressive strength of 7 and 28 day mortar specimens with increasing substitution (b) zeolite in the scheme containing equal amounts of natural and recycled sand, and (c) recycled sand in the scheme containing zeolite

The compressive strength of the 7-day samples made with an equal ratio of natural and recycled sand (without zeolite) was estimated at 14.56 MPa. With an increase in the percentage of cement replacement with zeolite to 10%, 15%, and 25%, the compressive strength decreased to 12.08, 14.5, and 12.7 MPa respectively, indicating reductions of 12%, 4.0%, and 8.12% respectively. The compressive strength of the 28-day samples made with an equal ratio of natural and recycled sand (without zeolite) was estimated at 26.99 MPa. With an increase in the percentage of cement replacement with zeolite to 10%, 15%, and 25%, the compressive strength decreased to 27.9, 23.68, and 27.36 MPa respectively, indicating reductions of 3.37%, 21.08%, and 37.1% respectively (Figure 4b).

A similar trend to Figure 4-a was observed for the decrease in compressive strength of the 7-day and 28-day samples with constant zeolite content due to an increase in the replacement of recycled sand, indicating that the presence of zeolite also has a detrimental effect on the compressive strength of both 7-day and 28-day samples (Figure 4c). However, the presence of zeolite has increased the compressive strength of the 7-day and 28-day samples compared to those without zeolite (Figure 4-a), which can be attributed to the filler and pozzolanic role of zeolite. Therefore, the optimal design in terms of both strength and environmental sustainability (green concrete) can be found in the mix with 15% zeolite replacement for cement and 50% recycled sand replacement for natural sand (15ZRM-50). The reason for the optimal strength performance can be attributed to the pozzolanic and filler functions of the replaced zeolite and the internal action of the replaced recycled aggregate. The environmental sustainability improvement arises from using zeolite instead of a portion of cement and using recycled sand instead of half of the natural sand.

In addition to the above, the significant difference in the 28-day strength of this mix compared to the mix without zeolite (RM-50), which had similar strength at 7 days, can be attributed to the delayed reaction of zeolite (pozzolanic reaction). This same reason can also explain the lack of difference in the 7-day compressive strength of the three mixes containing zeolite in Figure 4-b compared to the mix without zeolite.

The compressive strength of the produced samples meets at least the minimum requirements of the National Iranian Standards regulations [12] and all fall within the 20 MPa strength category (the highest strength classification for masonry mortar in Iran), indicating high-quality mortar production. The cement-to-sand ratio of 1:3 leads to an increase in the 28-day compressive strength of masonry mortar, such that, according to the Iranian National Standard,

compressive strength between 1 and 20 MPa is considered for masonry mortar. Nevertheless, considering the cement-to-sand ratio of 1:3 and 100% replacement of natural sand with recycled sand, it is still possible to achieve the highest strength category specified in the Iranian National Standard (mortar for masonry work).

3.5. Flexural Strength

The analysis of the results obtained at both 7 and 28 days shows that with an increase in the percentage of natural sand replaced by recycled sand and an increase in the percentage of cement replaced by zeolite, similar to the results obtained for compressive strength, flexural strength changes. These results are consistent with previous research findings [13]. In the 7-day samples, the flexural strength of the base sample made with natural sand was estimated at 4.85 MPa, and for replacement percentages of 50% and 100% of natural sand with recycled sand, the flexural strength was estimated at 4.2 and 3.27 MPa, respectively. These values indicate a 13% and 33% decrease in flexural strength, respectively. For the 28-day samples, the flexural strength of the base sample made with natural sand was estimated at 5.59 MPa, and for replacement percentages of 50% and 100% of natural sand with recycled sand, the flexural strength was estimated at 4.73 and 3.81 MPa, respectively. These values indicate a 15% and 32% decrease in flexural strength, respectively (Figure 5a).

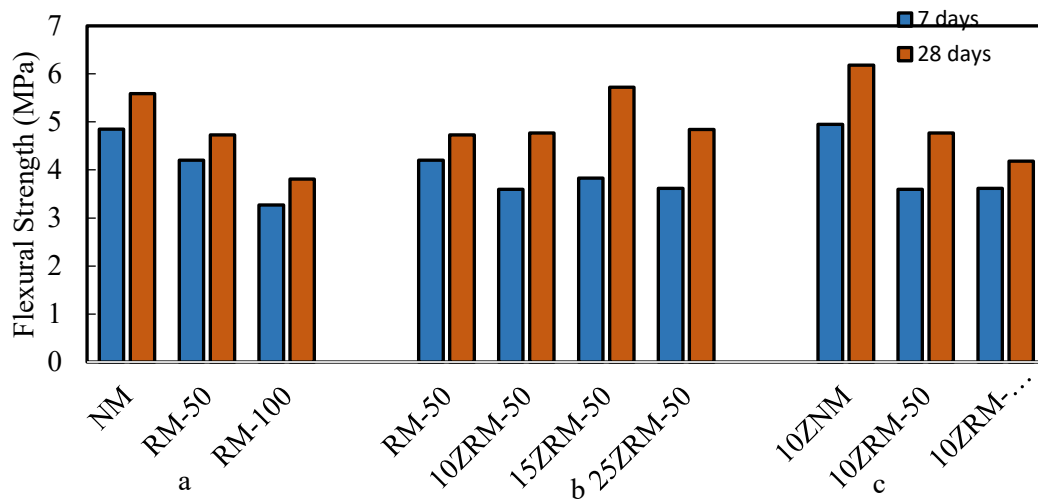


Fig. 5. Flexural strength of 7 and 28-day mortar specimens with increasing substitution of (a) recycled sand in the base scheme, (b) zeolite in the scheme containing equal amounts of natural and recycled sand, and (c) recycled sand in the scheme containing zeolite

The flexural strength of the 7-day samples, made with equal proportions of natural and recycled sand (without zeolite), was estimated at 4.2 MPa, and with an increase in the percentage of cement replacement with zeolite to 10%, 15%, and 25%, the flexural strength reached 3.63, 3.83, and 3.62 MPa, respectively, indicating a 14.2%, 8.8%, and 13.8% decrease in flexural strength, respectively. The flexural strength of the 28-day samples, made with equal proportions of natural and recycled sand (without zeolite), was estimated at 4.73 MPa, and with an increase in the percentage of cement replacement with zeolite to 10%, 15%, and 25%, the flexural strength reached 4.74, 4.72, and 4.84 MPa, respectively, indicating a 0.8%, 9.2%, and 3.2% decrease in flexural strength, respectively (Figure 5b). Additionally, a similar trend to Figure 5a was observed regarding the decrease in flexural strength of the 7-day and 28-day samples with constant zeolite values due to the increase in the replacement of recycled sand. It can be concluded that the presence of zeolite also has a reducing effect on the flexural strength of both 7-day and 28-day samples (Figure 5c). However, the presence of zeolite has increased the flexural strength of both 7-day and 28-day samples compared to samples without zeolite (Figure 5a), which can be attributed to the role of zeolite as a filler and pozzolan.

4. Conclusion

In this study, comprehensive studies and experiments were conducted on the performance and mechanical characteristics of mortars made with recycled sand and zeolite. Considering the priorities in sustainable development and the necessity of driving the construction industry towards these priorities in the country, the use of alternative

materials for aggregates, as well as the recycling of construction and demolition wastes, and reducing the use of cement by incorporating cementitious materials such as zeolite, are essential. Below are the key findings of this study:

By replacing natural sand with recycled sand, the performance clearly follows a downward trend, even saturating the recycled sand exacerbates this trend. However, replacing cement with zeolite does not strictly follow an upward or downward trend; rather, it may increase up to a certain point and then decrease.

Increasing the replacement of natural sand with recycled sand and the substitution of cement with zeolite reduces the workability time.

Substituting natural sand with recycled sand reduces the bulk density of both fresh and hardened concrete due to the higher porosity of recycled sand compared to natural sand. However, increasing the replacement of cement with zeolite does not significantly affect the bulk density of fresh and hardened concrete since the specific gravity of cement and zeolite are similar.

As evident, increasing the replacement of natural sand with recycled sand increases the water absorption percentage of concrete, reaching up to a 2.4% increase with 100% replacement of natural sand with recycled sand. However, there is no consistent increasing or decreasing trend in water absorption percentage with increasing replacement of cement with zeolite.

The compressive strength of mortars containing recycled sand at both 7 and 28 days is lower than those made with natural sand. Furthermore, an increase in the percentage of replacement of natural sand with recycled sand results in a decrease in compressive strength. For instance, the compressive strength for the base sample at 28 days reached 28.18 MPa, while for the sample with 100% recycled sand, it decreased to 12.39 MPa. Additionally, although the replacement of cement with zeolite did not significantly alter the compressive strength at 7 days, an increase in strength was observed at 28 days. Specifically, the compressive strength of concrete with an equal ratio of natural and recycled sand was 26.99 MPa, and with 15% replacement of zeolite, it increased to 32.68 MPa. Despite meeting the acceptable limits according to the Iranian National Standard, the compressive strength of the samples was within acceptable ranges.

The flexural strength at 28 days was 5.54 MPa for the base sample and 8.13 MPa for the sample made with 100% recycled sand. Similarly to compressive strength, while the replacement of cement with zeolite did not significantly affect the flexural strength at 7 days, an increase in strength was observed at 28 days. Specifically, the flexural strength of concrete with an equal ratio of natural and recycled sand was 4.75 MPa, and with 15% replacement of zeolite, it increased to 5.25 MPa.

In conclusion, it can be argued that the use of recycled sand, due to its lower quality, leads to a reduction in the quality of mortar. However, this reduction in quality can be compensated for to a very acceptable extent by replacing it with zeolite. Furthermore, the utilization of zeolite assists in reducing cement consumption and environmental pollution. On the other hand, given the increasing demand for utilizing construction waste and preventing environmental degradation, replacing natural sand with recycled sand, considering its suitable qualitative and mechanical performance, can lead to the concept of green concrete.

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Overview of Corrosion of Implants with TiAl6V4 Titanium Alloys in a Body-Simulating Environment

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Abstract

One way to replace organs is to fix and boost those using implants. Dental implants are very well-known. Each year, people use them 12 to 18 million times, with about 5.5 million in the EU alone. The rusting of biomaterials in implants that touch body fluids is a big problem. So, a lot of research is happening on this topic. Implants go through many reactions in the body with different pH levels. The type of alloy picked to build body implants has a big impact and needs careful choosing. TiAl6V4 is one such alloy. Scientists can study how the TiAl6V4 implant biomaterial reacts to a lab solution that mimics the body. Metabolic compounds control this solution. It has no added stuff, like lactic acid hydrogen peroxide, or mixes of both. They check electrochemical features by measuring open-circuit potential and impedance at different times. Studies of shape, makeup, and X-ray diffraction support the electrochemical findings before and after soaking in these solutions. The results show that the inflammatory product affects the implant. Also, metabolic lactic acid and hydrogen peroxide work together. They change how a titanium implant alloy reacts and resists rust.

Keywords: Corrosion, Implant, TiAl6V4 Alloy, Physiological Solution, Electrochemical Properties, Inflammatory Effect

1-1-Introduction

We must understand the basic structure of TiAl6V4 alloy. It is a biomaterial. It is to study how it reacts and corrodes under metabolic disturbances in body fluids. This alloy has an alpha plus beta structure with stabilizers. It has aluminum (alpha) and vanadium (beta). They give it good strength and corrosion resistance. Dentists often use this alloy. Remember that its elastic modulus is much higher than bone, which causes stress shielding. Also, implants made from this alloy are stable so that they can go through washing processes. This can lead to higher levels of vanadium and aluminum in soft tissues. These increases can cause diseases like osteomalacia, peripheral neuropathy, and Alzheimer's. So, this is a big worry when using implants and trying to keep people healthy. Studies show we need new implants that don't risk human health. So, researchers are making other alloys with safe components, like molybdenum (Mo). Doctors use TiAl6V4 a lot. It's strong, resists corrosion, and has good properties. It also works well with biological materials. However, researchers are working to reduce aluminum and vanadium ion leaching. They want to improve the corrosion resistance and body interaction of the TiAl6V4 alloy using coatings. [2-4]

To boost this alloy's metallurgical effectiveness, we can coat it with other elements and compounds. Bioactive glasses S4555 stand out as key materials to coat TiAl6V4. Research shows that composite coatings of bioactive glasses can improve TiAl6V4 substrates. They make them more biocompatible and corrosion-resistant. Scientists made two types of bioactive glass S4555 using the sol-gel method. The first is plain bioactive glass S455, and the second has 1% manganese added. They applied these bioactive glasses to the TiAl6V4 substrate by dipping. To reduce coating cracks, they mixed in 3% sodium alginate by weight to the bioactive glass solutions. They checked the results using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR-ATR), and scanning electron microscopy (SEM) on the bioactive glass powder. They then examined the coated samples with XRD, SEM, and biocompatibility tests, and checked on ion release from the substrate, wettability, and corrosion tests. Adding 1% manganese made the

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bioactive glass particles smaller and turned them from white to brown. The TiAl6V4 sample with the manganese-added bioactive glass coating did better than both the samples coated with plain bioactive glass S455 and the bare sample. The calcium-to-phosphate ratio for uncoated TiAl6V4 was 1.78, for simple coated was 1.81, and for doped coated was 1.90. The coated samples released one-third of the aluminum that the uncoated sample released. The TiAl6V4 sample with the doped coating released about 11% less vanadium than the TiAl6V4 sample with the undoped coating. The doped-coated sample had an average wettability angle of 16.42°, the undoped-coated sample had an average wettability angle of 14.96°, and the uncoated sample had an average wettability angle of 12.90°. The TiAl6V4 sample with the doped coating had a corrosion resistance of 606 kΩ/cm², while the uncoated sample had 2.3 MΩ/cm², and the undoped-coated sample had 3.1 MΩ/cm². TA6V is a titanium alloy that contains 90% titanium, 6% aluminum, and 4% vanadium. This alloy comes in different versions with small changes in its makeup. One type called TA6V-ELI has fewer of certain elements to make it easier to shape and tougher. People like both these titanium alloys because they're strong. [2-4]

Let's look at what's in these alloys and how strong they are:

TA6V has 6% aluminum, 4% vanadium, and the rest is titanium. TA6V's mechanical properties include an ultimate tensile strength (UTS) that ranges from 880 to 1,100 MPa (based on its form). Yield strength: 830 to 1,000 MPa (varies with biocompatibility behavior). Elongation: 10 to 25% (changes with form), while its elastic modulus falls between 110 and 120 GPa. Density: 4.43 to 4.51 grams per cubic centimeter (shifts depending on the form). TA6V ELI consists of 6% aluminum, 4% vanadium, and 0.13 to 0.20% intermediate elements (oxygen, nitrogen, carbon, hydrogen), with titanium making up the rest. [5]

This material has an ultimate tensile strength (UTS) between 880 and 1100 MPa. Keep in mind that its yield strength ranges from 830 to 1000 MPa (based on the form), and its elongation spans from 10 to 25% (also depending on the form). Other properties include elastic modulus: 110 to 120 GPa along with a density range of 4.43 to 4.51 grams per cubic centimeter (depending on the form). TA6V has strong mechanical properties such as a high strength-to-weight ratio, good resistance to corrosion, and excellent compatibility with living tissue, making it a good fit for medical uses. For instance, at room temperature, TA6V has a tensile strength of about 900 MPa and, yield strength of about 800 MPa, and it stretches about 15% before breaking. To sum up, people see TA6V as a versatile material and a breakthrough because it brings together unique physical and mechanical properties. [4-5]

Table 4 - Ti-6Al-4V composition. Adapted from [32].

Element	Nitrogen	Carbon	Hydrogen	Iron	Oxygen	Aluminium	Vanadium	Titanium
Composition (max.)	0.050	0.100	0.013	0.300	0.200	6.750	4.500	balance

Figure 7-1: General structure of alloy shape

1-2-History of Alloy Production

Metallurgist and MIT professor Stan Abkowitz invented titanium alloy in 1951 at the Watertown Arsenal lab, a US Army facility. He created this alloy by mixing molten aluminum and vanadium with pure molten titanium. The US Army first used it to make high-altitude spy planes in the 1950s. This new alloy and its use in these planes kicked off the titanium industry. Today, Ti-6Al-4V is the world's most popular titanium alloy. Making Ti-6Al-4V starts with the Kroll process, which is how most commercial pure titanium is made. This process heats titanium-rich ores like ilmenite

or rutile to produce liquid titanium tetrachloride (TiCl_4). Then, a process like making gas from crude oil purifies the liquid TiCl_4 . Next, adding magnesium to the liquid creates a sponge-like titanium material and a magnesium-based salt. Workers then compact and melt this sponge, adding the right amount of aluminum and vanadium to the melted titanium. After this step, they cast the Ti-6Al-4V alloy into ingots and other shapes. [6-8]

1-3- How to Make TiAl6V4 Alloy Using 3D Printing

In recent years, a new way to make this alloy has shown up called additive manufacturing. It not only makes production easier, but it can also give good money benefits to manufacturers. Many industries use the titanium alloy Ti6Al4V, like aerospace, defense, marine, power generation, car-making, and medical fields. They use it because it has unique chemical and physical traits. These include high strength for its weight, staying stable at high temperatures, fighting off tiredness and slow stretching, not rusting, and working well with the body. But Ti6Al4V alloy is hard to shape and costs a lot more than other materials it competes with. It's tough to work with because it doesn't move heat well, bends, and reacts with most cutting tools. This causes high heat near the cutting tool and too much bending, which wears out tools fast. When you're shaping it, the easy bending causes the metal to spring back, making it even harder to work with. It's worth noting that this springiness causes problems when making thin-walled parts, leading to wasteful cutting. Titanium alloys also tend to react with cutting tools, causing them to wear out fast and break too soon.[10]

1-4-The Additive Manufacturing Process

The AM process may lead to a significant reduction in material waste and production costs for expensive materials in comparison with conventional processing routes. Particularly, the AM technology, Selective Laser Melting (SLM), allows for complex component creation with a lattice or near-lattice shape that can be used with little or no more machining. However, manufacturing lattice-shaped Ti6Al4V components using SLM is quite challenging due to the inherent characteristics of the SLM process. Residual stresses are generated during solidification due to high cooling rates and temperature gradients, which affect fatigue and crack propagation at the very core. Additionally, the microstructure of fabricated parts will be anisotropic and predominantly consist of acicular α martensitic distributed within columnar beta grains because of the highly rapid cooling rates involved in maximizing part density. So, hardness, yield strength, and tensile strength were observed to be higher for SLM-Ti6Al4V parts compared to their conventional counterparts, though they had lower ductility. Henceforth, the use of such manufactured parts under service conditions is greatly limited in most industrial applications.

Post-processing heat treatment can convert martensitic steel into a dual phase α and β . This achieves a balance between ductility and strength. There is minimal research on the machinability of SLM-manufactured Ti6Al4V parts. SLM-produced Ti6Al4V parts have distinct characteristics compared to conventionally made ones. Their microstructure and mechanical properties are not the same. This paper discusses making Ti6Al4V alloy parts. It used selective laser melting and heat treatment to reduce stress. Researchers use a typical Ti6Al4V alloy as a reference. It will assess density, microstructure, phase, hardness, and residual stresses. We tested both the conventional parts and the SLM samples. These were in both non-processed (SLM) and relieved (SLM SR) states. We tested three material conditions. We measured surface roughness, cutting force, tool wear, and chip shape. This was to check machining performance. This study aimed to see if machining behavior changes with different processing routes. The key findings were: Conventional part densities were 99% high. Optimized SLM ones reached 99.70%. SLM processing produces parts with superior hardness compared to conventional methods. The conventional one, SLM, and SLM SR Ti6Al4V alloys showed two-phase microstructures: α and β . They had acicular α' martensitic in columnar β grains, plus some $\alpha + \beta$ phase. The residual stresses of the traditional alloy were the least. Only SLM had tensile residual stresses. SLM SR had the highest compressive residual stresses. The conventional alloy had a lower cutting force than other methods. Researchers found that the conventional alloy had the lowest cutting force. The highest was in the SLM SR alloy. Visual chip analysis found no significant deformation. This was true for both similar cutting lengths and different

materials. We can conclude that SLM-machined components have a better surface finish than normal parts. Microstructural changes have no bearing on machining behavior. This includes hardness increases and higher residual stresses from the SLM process. Traditional Ti6Al4V production guides the laser melting process for Ti6Al4V fabrication or, developed machining parameters suit Ti6Al4V created through selective laser melting.[9-11]

2-1-What is the Simulated Body Environment?

Modern biology and medical science must simulate the bodies of living things. This advance in technology made this possible. At one point, a university in Berlin took the first step towards achieving that goal. In most cases, the aim was to end animal testing in labs and schools. It would save millions of animals. You must complete this task at least a year after implementing the innovation. Berlin University introduced a human body modeling system in the 2000s. It was to replace 100 years of animal testing. Many medical experiments need reactions that mimic the real environment of the body to get accurate results. Depending on the experiment, researchers can use two methods to simulate the body. Medical experiments use cell cultures to examine drug effects in detail. Sometimes, we must test a substance in a living organism's watery environment. We want to see what happens when it contacts a certain drug. The second method, which checks the body's acidity, is also very important. The human body's internal environment maintains a pH range of 7.35-7.45. This acidity or alkalinity varies based on how the kidneys, lungs, and tissues work. The body should maintain a neutral pH. This means equal hydroxide and hydrogen ion levels. The body's different environments have different pH levels. For instance, saliva is not as acidic as urine. Saliva falls within a 6.2-7.6 range, whereas urine is acidic. Many, such as blood, must balance their pH. A disturbance can cause ailments and diseases. Your physiological system interconnects cellular and metabolic processes with precision. [19]

Blood must stay within a specific pH range. In simple terms, we measure the acidity or alkalinity of a substance by its hydrogen ion concentration. Many studies show that non-alkaline foods can raise body acidity. Include foods rich in protein, lemon juice, coffee, and acidic foods. This can lead to various diseases. The human body can generally self-regulate these conditions. For instance, it reacts by producing an alkaline substance that neutralizes acidic environments. High acidity means our bodies must produce more of this substance to balance it. A diet high in protein can increase body acidity. But, alkaline foods like fruits and veggies may help. They can reduce body acidity and promote good health. Researchers determine body pH using these methods: - Colorimetry - Different colors show different pH ranges. The manuals state the parameters of the indicators used in this method. One such color-changing indicator is litmus paper. It reflects a certain pH range, which varies by its color chart. - Electrometric - Of all methods, this one is the most accurate for measuring pH. First, calibrate the device. Then, plunge electrodes into the solution to get numerical values (a pH meter does this). This produces results based on those values. [18-20]

2-2-The Function of TiAl6V4 Alloy in Simulated Body Environment

Implant materials must be biocompatible, corrosion-resistant, and strong. They must also have good performance. Given these properties, surgeons choose safe metals and alloys for surgery. Of the biomaterials, metallic ones are the most many. They include Cr-Mo-Ni austenitic structural steels; titanium and its alloys; Co-based zinc alloys; tantalum; noble metals; and shape memory alloys. Also, ceramics, carbon, polymers, and composites, along with absorbable materials, are used. The key to the use of metals as implants is their biocompatibility. The reactions must cope with the implant, tissue, and body fluids. This depends on the implant type, location, and implantation method. This interaction between the implant and the tissue is reciprocal. Body harmony demands implants that sync with biological electricity. They need similar electromagnetic properties. Factors to consider for body implants include material type, surface properties, shape, and corrosion susceptibility. Corrosion and the aggressiveness of body fluids, including chloride, sodium, potassium, calcium, magnesium, and phosphate, are also factors. This aggressive behavior will stimulate the presence of proteins. Other factors affecting the rate of corrosion include body temperature, weight, and stereobiological status. These traits create a tough situation where only some factors can match. A thin, inert layer of

oxygen appears on the surface of modern materials within seconds. It somehow resists corrosion. For titanium, the thickness ranges from 2 to 5 nanometers and increases from 6 to 10. This process in a corrosion cell requires the presence of an electrolyte, an anode, and a cathode. In the corrosion process, the cathode consumes electrons while the anode produces electrons. The anode acts as an electron source, and then the electrons flow to the cathode. This process causes chemical degradation and corrosion of the steel. If both the cathode and anode are on the surface, corrosion will occur. The anodic reaction occurs at the surface and releases metal ions. These ions enter the environment. The cathodic reaction depends on the availability of electrons from the anode. Electrolytes can change the number of electrons used. This depends on their nature and environmental conditions. Electrodes of this type boost current flow to higher levels. Thus, we can predict that electronic consumption and production will increase. Other electrolytes can reduce the electrons used by the reactions. They can also reduce the current. The anodic process makes

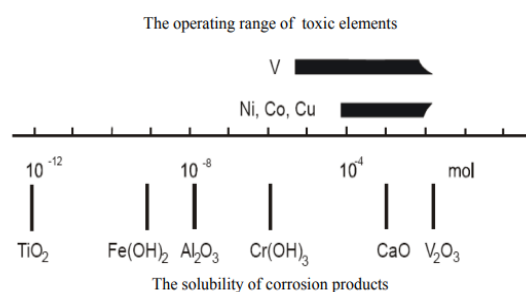


Figure 2-2: The degree of toxicity of elements

the metal more resistant to high electrochemical potentials. [1-6]

The corrosion strategies that could arise within the body can result in:

-Shortening the lifespan of the implant in the body.

- Limiting loading capabilities

-Decomposition of the merchandise may cause unwanted reactions. They could release metal ions into surrounding tissues. Some by-products may be toxic. [17-18]

Potential ache because of the infiltration of corrosion products into surrounding tissues (without any infection). Corrosion products enter the tissue environment in the shape of metallic ions. They might also affect or enter cells. Biocompatible alloys are safe for the body. They have less toxic metals. Corrosion resistance is vital for choosing therapy materials. It means making structures that resist bioelectrochemical corrosion. Biological current switches, semiconductor polarization changes, and electromagnetic waves stimulate reactions. Environmental responses occur where the implant is located. The key function is in semiconductors and piezoelectrics. Organic materials in the environment ease the transfer of biological quantities at a molecular level. This involves electron movement, protons, and proteins. The pH ranges from 5.7 to 9.0. It depends on how long the implant stays and the body's recovery process. Any metal implant will corrode in such an environment. The thickness from the corrosion cutting edge ranges from 10^{-6} to 10^{-9} A/Cm². This quantity corresponds to a corrosion rate expressed as 0.01 to 10 micrometers per year. Researchers predict the corrosion resistance of medical substances. They use potentiodynamic [13] and potentiostatic [14] methods. We have defined the corrosion capability waves and the thickness of the corrosion cutting edge. [17-18]. These studies allow professionals to expect the conduct of metals in corrosive environments. The existing paintings aim to test the corrosion resistance of the Ti6Al4V alloy in a body fluid-simulating environment. The purpose of the electrochemical research is to estimate the corrosion resistance of materials in a specific corrosive

environment. We tested various polished and ground samples in a solution called artificial saliva. The results show that the polished Ti6Al4V samples are more corrosion-resistant than the ground surfaces in the solutions. The polished samples corroded more as they became more cathodic. This reduced the difference in corrosion capacity. The ground samples varied from 0.15 to 0.2 volts. For the polished surface, it was only about 0.02 volts after passivation. The corrosion current in both cases increased with decreasing pH. The higher the cathodic capacity, the more the corrosion. The anodic density grows about the rising potential. So, acidifying the solution can boost anodic current density in both polished and ground samples in a competitive environment. This is due to a simpler formation of a passive layer in a higher pH solution. Corrosion protection disintegrates in acidic environments under specific voltage conditions. Passivation for both surface preparation states is approximately 1 volt. The dark pigment shows an inert product. Polished samples state a more inactive form. In contrast, ground samples show little inactivation. Polished specimens exhibit great corrosion resistance. Acidity strengthens to forge a dense, protective barrier in a flash. Acidity strengthens in harsh environments, forming a thick, unreactive barrier. Specimens polished and ground in acidic environments undergo swift passivation. The duration of the passivation process on ground and polished surfaces is about 1-2 volts in power. During this test, the floor samples experienced pitting and corrosion. Pore size depends on space. The acidic conditions caused larger, deeper pits. In the pH=7 solution, the pits were rarer, smaller, and shallower. Polished Ti6Al4V alloy samples with no surface damage were more stable than the others. Organic compounds can react and decompose. These complex processes can cause infectious diseases or injuries in biomedical applications. Metal implants involve chemical reactions, electrical interactions, and biochemical processes. These interactions combine with specific physiological factors to create issues. In the past 20 years, titanium and its alloys have drawn interest in surgery and bone replacement. They have unique mechanical, chemical, and biological properties. Titanium and its alloys resist corrosion and are biocompatible with living tissue. The positive response is due to titanium oxide forming on its surface. This oxide layer is 1 to 5 nanometers thick. Body fluids can, over time, expose a titanium-titanium alloy. The alloy can then prevent the release of metal ions. This native oxide layer prevents corrosion from spreading on the edge surface. Of biomaterials e. Reactive oxygen species, proteins, cells, or organic ions on the surface can break down the oxide film. Activating the surface of the biomaterial initiates a corrosion cycle. An implant failure impacts mobility, mouth placement, and material hold. So, the key to the success of implants is stable interactions between them and the surrounding tissues. Infectious processes like mucositis and peri-implantitis may cause rejection. Implants are in the mouth, where bacteria have built up on their surfaces. Also, bone and bacteria flow under working loads. This transports titanium fragments into the tissue around the implant. It also spreads bacteria around the implant into the fixture-abutment connection. Bones, bacteria, and by-products contribute to implant failure. So do worn and corroded fixed abutment joints. This causes biological (mucositis, peri-implant inflammation) and mechanical (corrosion, screw loosening, fracture, fatigue) issues. Bone also plays an important role in dental implants. The tooth surface is always lying in bone through the gingival sulcus. Bone can be a sensitive electrical conductor. The gums can mimic electrical cells. They help break down the oxide layer in the body.[16-17] Electrochemical corrosion of titanium alloys can cause pitting. It may stop the flow of corrosion products. [12] Two factors can affect titanium coatings. They are inflammation of surrounding tissue and acidic conditions from bacteria. These can harm the coatings' behavior and corrosion resistance. They can cause local acidification and damage the titanium oxide layer. This inhibits titanium's ability to regenerate. We must use environmental factors in lab experiments. They are key to studying the physics of natural products. We want to see how biomass degrades over time. We also want to understand processes after metal incorporation at the interface of physiology and organisms. Hank's solution is a famous simulated environment. It explores biological processes and degradation. Other formulations include Hank's solution with and without hydrogen peroxide (H₂O₂), with and without albumin, and Ringer's solution. Ringer's solution combines albumin, hydrogen peroxide, fluoride ions, and lactic acid. Artificial saliva is another lab solution. [19] It contains lactic acid, a 0.9% salt solution with 0.1 molar acid, and phosphate buffer salts. We test the performance and corrosion properties of a Ti6Al4V alloy. Hank dissolved it in a solution with added hydrogen peroxide. He then heated it to room temperature using lactic acid as a reagent. These factors can affect the implant's corrosion resistance. So, the cause of corrosion is unclear. Lactic acid is a weak organic acid. Biochemical processes use it because it is important. During exercise, the body's muscles produce it. This lowers its blood circulation. It gets energy from glucose metabolism without oxygen. The mouth, foods, and anyone can also produce

lactic acid. Hydrogen peroxide, a reactive oxygen, triggers inflammation in the human body. It adds to Hank's compound and lactic acid in a sequence. [1-4]

We should investigate the effect of time on the reactions and corrosion of the Ti6Al4V titanium alloy used as an implant. We will do this by adding an electrolyte containing acid, hydrogen peroxide, and a mixture of the two. This study offers precise details on titanium implant degradation mechanisms. It explores degradation under acute conditions, involving inflammation and lactic acid. These factors stimulate a physical reaction. Thermal conditions trigger alloy cast deterioration, with chemical additives accelerating decay. Natural pigment chemicals combine to influence alloy cast degradation, as seen [11-1].

3-1-Conclusions

Tests reveal that heat causes composite implant degradation over time. Titanium alloy implants can last longer if we avoid harmful conditions. They can cause severe corrosion from lactic acid and hydrogen peroxide in organic solutions, like Hank's. Tests on corrosion-resistant Ti6Al4V alloy using Ringer's solution and a synthetic Lar potentiodynamic method show that: In both solutions, the polished samples resisted corrosion better than the dried ones. The resin produces more corrosion than the Ringer solution. Soil samples pit and corrode in synthetic saliva. In Ringer's solution, a passive layer forms on its surface. The surface of other coating materials for implants may or may not be smooth.

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A new fuzzy-interval regression method with one approach

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ABSTRACT

One of the most important issues of multi-criteria decision-making in the economic world today is solving the problem of choosing the location of facilities, the problem of choosing the location of facilities is one of the problems of multi-criteria decision-making. Sometimes in these problems, options and criteria are expressed quantitatively and qualitatively. As these numbers are imprecise and fuzzy numbers, normal fuzzy numbers are used to rank such problems. In most cases, it becomes difficult to rank the options and criteria that are in between. In these cases, we use fuzzy-interval numbers and their ranking using fuzzy-interval MCDM methods. The proposed methods solve some of the limitations and defects in the common multi-criteria decision-making (MCDM) methods and provide a platform for better, more accurate decision-making and choosing the most favorable option. In this article, the proposed method is used to rank a real practical problem related to choosing a suitable place to dig a pit to bury urban wet waste in one of the big cities of Iran. This proposed method is used with other methods such as IVF-TOPSIS and IVF-COPRAS is also compared and in the end, we conclude that this method has a more accurate rating than other methods in addition to its simplicity and ease of calculation.

Keywords: MCDM, Facility location selection problem and interval fuzzy numbers, IVF-TOPSIS and IVF-COPRAS

1. INTRODUCTION

Choosing the right location of the facility is one of the most important and strategic decisions in various industries, which has a significant effect on the performance and efficiency of the organization. Choosing a good location has a great impact on the economic survival of the organization. By choosing a suitable location, it can prevent additional costs and make the organization more profitable. Choosing the right location of the facility is one of the multi-criteria decision issues that many authors were paid attention to it.

Isalo et al. used fuzzy logic and Analytical Network Process (ANP) method to determine the suitable place for landfilling municipal solid waste produced in the city of Kohk, Qom, Iran [1]. It created a fuzzy environment. In order to avoid the complex operation of fuzzy calculation, the linguistic variables expressed by triangular fuzzy numbers were converted into clear numbers by displaying the graded average [2]. Wei et al. a fuzzy ANP method to solve the location of the dry port was developed under uncertain conditions [3]. Nazeri et al. also Chen used MCDM method based on fuzzy AHP to select the best landfill site based on a set of decision criteria. [4] They applied the mentioned method to a hypothetical problem with four different regions. The results of using the computer program showed that the accuracy is improved compared to the traditional methods and the computing time needed to rank and choose the appropriate landfill site is significantly reduced [5]. Wang and Chen [6] investigated the fuzzy AHP method and then presented the fuzzy LinPreRa method. They applied the proposed method to solve the facility location selection problem, which was investigated by Kahraman et al. [8] The results of their paper showed that the presented fuzzy LinPreRa method is a simple and practical method to provide a mechanism to improve consistency in the fuzzy AHP

method. Hu et al. [7] integrated AHP and multiple-choice goal programming (MCGP) methods as a decision aid to obtain a suitable house from many alternative locations for renters according to their preferences and needs. Kahraman et al. [8] of four fuzzy MCDM methods, i.e. fuzzy group decision model proposed by Blain [9], fuzzy combined evaluation, forward weighted objective method by Yager [10] and fuzzy AHP to solve facility location selection problems. They used quantitative and qualitative criteria. Wibowo and Deng [11] presented a fuzzy multi-criteria decision-making approach to effectively solve the hotel location evaluation and selection problem, the proposed method was based on pairwise comparisons and consensus building process. They also developed an algorithm to determine the overall performance of each alternative site according to the criteria on which the selection was made. Safari et al. [12] presented a fuzzy TOPSIS method to select a suitable site for mineral processing plant for Sangan iron ore mine. Fuzzy AHP methods and fuzzy TOPSIS TOPSIS methods were used for the problem of facility location selection. They used two methods to solve the problem of choosing the location of a textile company's facilities in Türkiye. They also discussed the similarities and differences between the two methods. Ertugrul and Karakasoglu used Fuzzy AHP methods and Fuzzy TOPSIS methods for the plant location selection problem of a textile company in Turkey. [13] Mokhtarian [14] presented a new Fuzzy Weighted Average (FWA) method based on each left and right scores. The proposed method was used to solve the regional location selection problem related to determining the appropriate location for an oil and gas station. Chouand Chang [15] developed a fuzzy MCDM model and applied it to evaluate the locations of distribution centers in China and choose the best model for investment from the perspective of a Taiwanese manufacturer. In addition, Chu et al. [16] introduced a simple fuzzy additive weighting system (FSAWS) to solve facility location selection problems under group decision-making conditions. Orthogrol [17] presented a fuzzy TOPSIS method in which different distance measurement methods were used and the results of their application were compared. The proposed method was applied to a problem of choosing the location of a textile company's facilities in Türkiye. Vahidnia et al. [18] developed a multi-criteria decision analysis process that combined geographic information system (GIS) analysis with fuzzy AHP. They used this process to determine the optimal location for a new hospital in the urban area of Tehran. Mokhtarian and Hadi Venche [19] proposed a new fuzzy TOPSIS method based on left and right scores. They applied the proposed method to solve three numerical examples, the third of which was a real application, which was the selection of an industrial area among several industrial areas to build a dairy products factory. Shen and Yu [20] used the dynamic product-process change matrix as a map to help managers relate selection criteria to the requirements of operation strategies for facility location selection. They also proposed an empirical fuzzy approach including a risk judgment method for specific decision-making environment and manager authorities under group decision-making processes. In order to demonstrate the efficiency of the developed system, an experimental case study was conducted. The results of their method showed interesting managerial implications.

Ka [21] considered transportation, economic level, infrastructure facilities, trade level, political environment and cost as important factors that affect the location selection of dry ports in China. Based on these factors, they combined Fuzzy AHP and ELECTRE. The method (Elimination ET Choice Translating Reality) was used to solve a real practical problem. Given that, the proposed method was considered ambiguous and the preference of factors affecting the location selection problem, it was suitable for solving real practical problems. Lee [22] proposed a fuzzy MCDM method to select locations for distribution centers. Devi and Yadav [23] proposed an intuitive fuzzy ELECTRE method so that the ranking of options according to each criterion and the weights of the criteria were expressed with triangular intuitive fuzzy sets. They applied the presented method to a plant location selection problem. While Vafaeipour and his colleagues (2014) used the combination of Savar and Vaspas methods to prioritize regions and cities to determine the location of solar power plants in the future [24]. In 2019, Khyberi et al. used the best worst (BWM) method to find the best place for bioethanol production in an evaluation framework based on three dimensions of sustainability (economic, environmental and social) in Iran [25]. In 2020, Sekar and his colleagues used the entropy-based TOPSIS method under the IVPF environment to select the location of the hydrogen production facility for the Black Sea. Their goal was to select the most suitable location in northern Turkey for the hydrogen sulfide (H₂S) decomposition power

plant in their study. They used the entropy method based on the similarity to the ideal solution and IVPF to deal with uncertain data [26]. In 2022, Ebadi et al presented a limited hybrid decision-making model to select the best location for recycling facilities in Istanbul, Turkey. Their method is a combination of the best-worst hierarchical classification method (H-SBWM) and limited hybrid compromise solution (COCOSO).) and the weight was limited, they used this method in a case study of six candidate sites in Istanbul to select the best site for establishing a recycling site. [27]

Considering that in most cases of facility location selection, it is sometimes difficult for the expert to accurately determine the degree of membership for each element of the fuzzy sets that are considered for ranking the options according to the criteria. The weights are expressed as a number in the range [0, 1], the values of the options according to the criteria and the weight values of the criteria are expressed by IVFN. Therefore, IVF-MCDM methods should be used to solve such interval fuzzy MCDM problems. Given that the proposed method is based on the concept of interval fuzzy number set (IVFS), we first state some basic definitions and arithmetic operations on this number.

18. THE PROPOSED FUZZY-INTERVAL METHOD

The WASPAS method is one of the new multi-criteria decision making methods that was introduced in 2012 by Zavadskas et al. This method is a combination of two models, WSM (weighted sum model) and WPM (weighted model). The advantage of this method is more accuracy compared to other methods.

If $A = [A_{ij}]_{n \times m}$ is a decision matrix as shown below.

A	w_1	w_2	...	w_j	...	w_n
	c_1	c_2	...	c_j	...	c_n
A_1	A_{11}	A_{12}	...	A_{1j}	...	A_{1n}
\vdots	\vdots	\vdots	...	\vdots	...	\vdots
A_i	A_{i1}	A_{i2}	...	A_{ij}	...	A_{in}
\vdots	\vdots	\vdots	...	\vdots	...	\vdots
A_m	A_{m1}	A_{m2}	...	A_{mj}	...	A_{mn}

Where $A_{ij} = [(a_{ij1}^l, a_{ij2}^l, a_{ij3}^l), (a_{ij1}^u, a_{ij2}^u, a_{ij3}^u)]$ and the weight vector $w_j = [((w)_1^l, (w)_2^l, (w)_3^l), ((w)_1^u, (w)_2^u, (w)_3^u)]$ is as follows (1)

1. We assume that B is the normalized matrix, A which is calculated with the following formulas (positive criteria and negative criteria).

$$\tilde{B}_{ij} = \left[\left(\frac{a_{ij1}^l}{a^*}, \frac{a_{ij2}^l}{a^*}, \frac{a_{ij3}^l}{a^*} \right), \left(\frac{a_{ij1}^u}{a^*}, \frac{a_{ij2}^u}{a^*}, \frac{a_{ij3}^u}{a^*} \right) \right]$$

$$i = 1, \dots, n \quad j \in \Omega_b$$

$$B_{ij} = \left[\left(\frac{\bar{a}_{ij1}^u}{a_{ij3}^u}, \frac{\bar{a}_{ij2}^u}{a_{ij2}^u}, \frac{\bar{a}_{ij3}^u}{a_{ij1}^u} \right), \left(\frac{\bar{a}_{ij1}^l}{a_{ij3}^l}, \frac{\bar{a}_{ij2}^l}{a_{ij2}^l}, \frac{\bar{a}_{ij3}^l}{a_{ij1}^l} \right) \right]$$

$$i = 1, \dots, n \quad j \in \Omega_c$$

(2)

2. We define if and then we get the center of gravity from the following relationship.

$$b'_{ij} = \frac{\sum_{j=1}^2 (a_j^L - a_{j-1}^L) \left[(\mu_j^L - 1) * \left(\frac{2a_{j-1}^L + a_j^L}{3} \right) + \mu_j^L * \left(\frac{a_{j-1}^L + 2a_j^L}{3} \right) \right] + \sum_{j=1}^2 (a_j^U - a_{j-1}^U) \left[(\mu_j^U - 1) * \left(\frac{2a_{j-1}^U + a_j^U}{3} \right) + \mu_j^U * \left(\frac{a_{j-1}^U + 2a_j^U}{3} \right) \right]}{\sum_{j=1}^2 (a_j^L - a_{j-1}^L) (\mu_{j-1}^L + \mu_j^L) + \sum_{j=1}^2 (a_j^U - a_{j-1}^U) (\mu_{j-1}^U + \mu_j^U)}$$

(3)

3. Calculate the relative importance of options

$$Q_i^1 = \sum_{j=1}^n b'_{ij} w_j$$

$$Q_i^2 = \prod_{j=1}^N (b'_{ij})^{w_j}$$

(4)

4. Calculation of the common criterion: In this step, an equal ratio should be calculated through the 3 importance of options.

$$Q_i = 0.5(Q_i^1)^1 + 0.5(Q_i^2)^2_{(\Delta)}$$

Options can be ranked based on value, but the accuracy and effectiveness of the WASPAS method is that the relative importance of the i-th option is calculated through Landa's calculation in the following formula.

$$_{(6)} Q_i = \lambda Q_i^1 + (1 - \lambda) Q_i^2$$

To calculate Landai, we use the basis of standard deviation:

$$\lambda = \frac{\delta^2(Q_i^2)}{\delta^2(Q_i^1) + \delta^2(Q_i^2)}_{(7)}$$

$$\delta^2(Q_i^1) = \sum_{i=1}^n \sum_{j=1}^n w_j^2 \delta^2(b'_{ij}) \quad (8)$$

$$\delta^2(Q_i^2) = \sum_{i=1}^n \left[\frac{\prod_{j=1}^n (b'_{ij})^{w_j} \times W_{ij}}{(b'_{ij})^{w_j} \times (b'_{ij})^{1-w_j}} \right] \delta^2(b'_{ii}) \quad (9)$$

3. BASIC CONCEPT $IVFS_S$

In this section, we give some definitions and operators on IVFS numbers (set of interval fuzzy numbers) below.

Definition 1). If it is an infinite set, IVFS is defined in the reference set as follows:

$$X \rightarrow \{[a, b] \mid a \leq b, \in [0, 1]\} \quad (10)$$

In this case, X was defined as IFVS(X) .

Definition 2) If $A(x) = [A^L(x), A^U(x)]$, $A \in IVFS$, $0 \leq A^L(x) \leq A^U(x) \leq 1$ and $A \ x \in X$

Then lower fuzzy set $A^L(x)$ and upper fuzzy set $A^U(x)$ are defined as
 $A^L(x): x \rightarrow [0, 1]$, $A^U(x): x \rightarrow [0, 1]$

Definition 3) If A is an IVFS, it has the following properties:

1. It is convex.
2. It is closed and bounded in the displayed interval.
3. A defined as an ordinary number $IVFN$ in the interval of X set and denote it by $IVFN_{(x)}$
4. Suppose two general triangular fuzzy numbers (GTFN) h^u, h^l and be real numbers $a^l_1, a^l_2, a^l_3, a^u_1, a^u_2, a^u_3$.

Then A is defined as GTFN on the set X as follows:

$$A = [A^L, A^U] = [(a^l_1, a^l_2, a^l_3), (a^u_1, a^u_2, a^u_3)]$$

That $0 \leq a^l_1 \leq a^l_2 \leq a^l_3 \leq 1$ and $0 \leq a^u_1 \leq a^u_2 \leq a^u_3 \leq 1$

And also $1 \leq h^l_A \leq h^u_A \leq 0$, $a^l_3 \leq a^u_3$ and $a^u_1 \leq a^l_1$

Then $A^L = (a^l_1, a^l_2, a^l_3, h^l_A)$, $A^U = (a^u_1, a^u_2, a^u_3, h^u_A)$

That is $A^L \subset A^U$

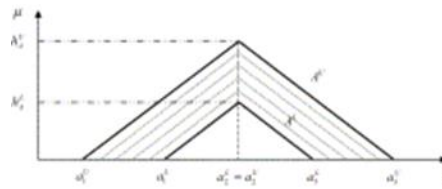


Figure 1

A GTFN is defined by two triangular fuzzy numbers shown in Figure 1, and their membership degree function is defined as follows.

$$A^L(x) = \begin{cases} h_A^L \frac{(x - a_1^L)}{a_2^L - a_1^L} & a_1^L \leq x \leq a_2^L \\ h_A^L & x = a_2^L \\ h_A^L \frac{(a_3^L - x)}{a_3^L - a_2^L} & a_2^L \leq x \leq a_3^L \\ 0 & \text{other wise} \end{cases}$$

$$A^U(x) = \begin{cases} h_A^U \frac{(x - a_1^U)}{a_2^U - a_1^U} & a_1^U \leq x \leq a_2^U \\ h_A^U & x = a_2^U \\ h_A^U \frac{(a_3^U - x)}{a_3^U - a_2^U} & a_2^U \leq x \leq a_3^U \\ 0 & \text{other wise} \end{cases}$$

,it is $h_A^u = h_A^L = 1$ If GTFN is a normal IVTFN .

$h_A^u = h_A^L = 1$ and $a_1^u = a_2^u = a_3^u = 1$ and $a_1^L = a_2^L = a_3^L = 1$ If then T A is a regular number.

Definition5) If A and B are two normal IVTFN :numbers defined as follows

$$A = [A_1^L, A_2^U] = [(a_1^L, a_2^L, a_3^L), (a_1^u, a_2^u, a_3^u)]$$

$$(13) A = [B_1^L, B_2^U] = [(b_1^L, b_2^L, b_3^L), (b_1^u, b_2^u, b_3^u)]$$

Then the arithmetic operators between B and A .are as follows:

$$A + B = [(a_1^L + b_1^L, a_2^L + b_2^L, a_3^L + b_3^L), (a_1^u + b_1^u, a_2^u + b_2^u, a_3^u + b_3^u)]$$

$$A - B = [(a_1^L - b_1^L, a_2^L - b_2^L, a_3^L - b_3^L), (a_1^u - b_1^u, a_2^u - b_2^u, a_3^u - b_3^u)]$$

$$A \times B = \left[\left(a_1^l \times b_1^l, a_2^l \times b_2^l, a_3^l \times b_3^l \right), \left(a_1^u \times b_1^u, a_2^u \times b_2^u, a_3^u \times b_3^u \right) \right]$$

$$(14) \frac{A}{B} = \left[\left(\frac{a_1^l}{b_1^l}, \frac{a_2^l}{b_2^l}, \frac{a_3^l}{b_3^l} \right), \left(\frac{a_1^u}{b_1^u}, \frac{a_2^u}{b_2^u}, \frac{a_3^u}{b_3^u} \right) \right]$$

4.RECDOMMENDED IVF-WASPAS METHOD

WASPAS method, One of the new methods of multi-criteria decision making was introduced in 2012 by Zavadskas et al. This method is a combination of two models WSM (weighted sum model) and WPM (weighted product model). The advantage of this method is more accuracy compared to other methods.

If $A = [A_{ij}]_{n \times m}$ is a decision matrix as shown below:

$$\begin{array}{ccccccc}
 A & w_1 & w_2 & \cdots & w_j & \cdots & w_n \\
 & c_1 & c_2 & \cdots & c_j & \cdots & c_n \\
 A_1 & A_{11} & A_{12} & \cdots & A_{1j} & \cdots & A_{1n} \\
 \vdots & \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\
 A_i & A_{i1} & A_{i2} & \cdots & A_{ij} & \cdots & A_{in} \\
 \vdots & \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\
 A_m & A_{m1} & A_{m2} & \cdots & A_{im} & \cdots & A_{im}
 \end{array}$$

In which $A_{ij} = \left[\left(a_{ij1}^l, a_{ij2}^l, a_{ij3}^l \right), \left(a_{ij1}^u, a_{ij2}^u, a_{ij3}^u \right) \right]$ and the weight vector $w_j = \left[\left((w)_1^l, (w)_2^l, (w)_3^l \right), \left((w)_1^u, (w)_2^u, (w)_3^u \right) \right]$ is as follows.

1. We assume that B is the normalized matrix, A which is calculated with the following formulas (positive criteria and negative criteria).

$$\tilde{B}_{ij} = \left[\left(\frac{a'_{ij1}}{a^*}, \frac{a'_{ij2}}{a^*}, \frac{a'_{ij3}}{a^*} \right), \left(\frac{a^u_{ij1}}{a^*}, \frac{a^u_{ij2}}{a^*}, \frac{a^u_{ij3}}{a^*} \right) \right]$$

$$i = 1, \dots, n \quad j \in \Omega_b$$

$$B_{ij} = \left[\left(\frac{\bar{a}}{a_{ij3}^u}, \frac{\bar{a}}{a_{ij2}^u}, \frac{\bar{a}}{a_{ij1}^u} \right), \left(\frac{\bar{a}}{a_{ij3}^l}, \frac{\bar{a}}{a_{ij2}^l}, \frac{\bar{a}}{a_{ij1}^l} \right) \right]$$

$$i = 1, \dots, n \quad j \in \Omega_c$$

2. We define if $B^L = (a_1^L, a_2^L, a_3^L, \mu_j^L)$ and $B^U = (a_1^U, a_2^U, a_3^U, \mu_j^U)$. Then we get the center of gravity from the following relationship [28].

$$b'_{ij} = \frac{\sum_{j=1}^2 (a_j^L - a_{j-1}^L) \left[(\mu_j^{L-1} * (\frac{2a_{j-1}^L + a_j^L}{3})) + \mu_j^L * (\frac{a_{j-1}^L + 2a_j^L}{3}) \right] + \sum_{j=1}^2 (a_j^U - a_{j-1}^U) \left[(\mu_j^{U-1} * (\frac{2a_{j-1}^U + a_j^U}{3})) + \mu_j^U * (\frac{a_{j-1}^U + 2a_j^U}{3}) \right]}{\sum_{j=1}^2 (a_j^L - a_{j-1}^L) (\mu_{j-1}^L + \mu_j^L) + \sum_{j=1}^2 (a_j^U - a_{j-1}^U) (\mu_{j-1}^U + \mu_j^U)} \quad (15)$$

3. Calculate the relative importance of option

$$Q_i^1 = \sum_{j=1}^n b'_{ij} w_j$$

$$(16) Q_i^2 = \prod_{j=1}^N (b'_{ij})^{w_j}$$

4. Calculation of the common criterion: In this step, the equal ratio should be calculated through the three importance of the options.

$$(17) Q_i = 0.5(Q_i^1) + 0.5(Q_i^2)$$

Options can be ranked based on value, but the accuracy and effectiveness of the WASPAS method is that the relative importance of the i-th option is calculated through Landa's calculation in the following formula.

$$Q_i = \lambda Q_i^1 + (1 - \lambda) Q_i^2 \quad (18)$$

To calculate Landai, we use the basis of standard deviation

$$\lambda = \frac{\delta^2(Q_i^2)}{\delta^2(Q_i^1) + \delta^2(Q_i^2)}$$

$$\delta^2(Q_i^1) = \sum_{i=1}^n \sum w_j^2 \delta^2(b'_{ij})$$

$$\delta^2(Q_i^2) = \sum_{i=1}^n \left[\frac{\prod_{j=1}^n (b'_{ij})^{w_j} \times W_{ij}}{(b'_{ij})^{w_j} \times (b'_{ij})^{1-w_j}} \right]^2 \delta^2(b'_{ij})$$

$$(19) \delta^2(n_{ij}) = (0.5 \times b'_{ij})^2$$

5. NUMERICAL EXAMPLES

One of the most important decision-making issues is the issue of choosing the location of facilities. In such issues, options and criteria are expressed quantitatively and qualitatively.

The issue of choosing the location of the facility is an important factor for maintaining the survival of a company in a competitive environment. It should be noted that the inappropriate choice of the location of the facility has negative consequences and may cause irreparable losses to the company. Production or service capacity, reducing total costs related to production or service operations, gaining additional profit, increasing customer satisfaction, profitability of savings and return, ease of development in the future and minimizing investment in equipment in choosing a location with many facilities. It is important to pay attention to them in making decisions.

In this article, we present the example solved in Mokhtarian et al.'s (2014) article, which presents a real practical problem related to digging several pits for wet waste disposal in one of the big cities of Iran.

In one of the largest cities of Iran, Isfahan, the amount of urban wet waste production has increased significantly in recent years. Therefore, it has become one of the serious urban problems for the said city. It should be stated that the city of Isfahan has an area of about four hundred and seventy seven square kilometers. It is located in three geographical areas, desert, mountain and plain. Due to the strategic location of Isfahan city, major industrial centers are located around it. It should also be mentioned that Isfahan has 14 megacities and a population of one million, nine hundred and eighty thousand people.

To solve the problem of disposal of wet waste, the municipality has decided to dig pits for burying urban wet waste. The municipality has taken help from a four-person team to make a decision. The team considered three locations approximately in the northwest (A1), east (A2) and southeast (A3) of the city to dig several pits and each of the locations was based on seven decision criteria including: ease of access to the location (C1), the risk of future damage to the environment (C2), the monetary value (in \$106) of the location (C3), the amount of decomposed compounds in the soil (C4), the ease of future expansion (C5), the amount of annual winds in the direction of the location to the city (C6) and the risk of placing the place in the direction of city development (C7) is evaluated, as well as the absolute ranking by considering the criteria C1, C2, C4, C5, C6 and C7 by IVF language variables that are in Table 3 have been defined and evaluated. On the other hand, criteria C1, C4 and C5 are considered as profit criteria and criteria C2, C3, C6 and C7 are considered as profit criteria.

The weights of the relative importance of the seven criteria using IVF language variables defined in Table 2, as well as Table No. 1, convert the comments expressed as linguistic

variables into fuzzy numbers - interval. Table 4 shows the initial evaluation information. Finally, the final opinion about options and weights is the average opinion of four experts, that is, $\tilde{w}_j = (\tilde{w}_{1j} + \tilde{w}_{2j} + \tilde{w}_{3j} + \tilde{w}_{4j})/4$ and $\tilde{A}_{ij} = (\tilde{A}_{1ij} + \tilde{A}_{2ij} + \tilde{A}_{3ij} + \tilde{A}_{4ij})/4$,

Table1.Comments in the form of language variables

Linguistic variables	Interval Valued fuzzy number
Very low(VL)	[(0.00,0.00,1.00),(0.00,0.00,1.50)]
low(L)	[(0.50,1.00,2.50),(0.00,1.00,3.50)]
relatively low(ML)	[(1.50,3.00,4.50),(0.00,3.00,5.50)]
Medium(M)	[(3.50,5.00,6.50),(2.50,7.00,9.50)]
Fairly good(MH)	[(5.50,7.00,8.00),(4.50,7.00,9.00)]
good(H)	[(7.50,9.00,9.50),(5.50,9.00,10.00)]
Very Good(VH)	[(9.50,10.00,10.00),(8.50,10.00,10.00)]

Table2

Linguistic variables	Fuzzy number Interval Valued
Very low(V1)	[(0.00,0.00,0.10),(0.00,0.00,0.15)]
low(L)	[(0.05,0.10,0.25),(0.00,0.10,0.35)]
relatively low(ML)	[(0.15,0.30,0.45),(0.00,0.30,0.55)]
Medium(M)	[(0.35,0.50,0.65),(0.25,0.50,0.75)]
Fairly good(MH)	[(0.55,0.70,0.80),(0.45,0.70,0.95)]
good(H)	[(0.75,0.90,0.95),(0.55,0.90,1.00)]
Very Good(VH)	[(0.95,1.00,1.00),(0.85,1.00,1.00)]

Table3

Criteria	DM1	DM2	DM3	DM4	Aggregated INFN
C1	H	VH	M	MH	[(0.65,0.78,0.85),(0.53,0.78,0.93)]
C2	VH	MH	H	H	[(0.75,0.88,0.93),(0.60,0.88,0.99)]
C3	M	M	ML	H	[(0.40,0.55,0.68),(0.26,0.55,0.76)]

C4	H	VH	MH	VH	$[(0.80,0.90,0.94), (0.68,0.90,0.99)]$
C5	VH	H	VH	MH	$[(0.80,0.90,0.94), (0.68,0.90,0.90)]$
C6	MH	M	ML	H	$[(0.45,0.60,0.71), (0.31,0.60,0.81)]$
C7	H	VH	VH	VH	$[(0.90,0.98,0.99), (0.78,0.98,1.00)]$

Table4

Criteria	Alternatives	DMs				Aggregated IVFNs	Normalized IVFNs
		DM1	DM2	DM3	DM4		
C1	A1	M	MH	L	L	$[(2.50,3.50,4.88), (1.75,3.50,6.00)]$	$[(0.25,0.35,0.49), (0.18,0.35,0.60)]$
	A2	H	H	VH	VH	$[(8.50,9.50,9.75), (7.00,9.50,10.00)]$	$[(0.85,0.95,0.98), (0.70,0.95,1.00)]$
	A3	H	MH	L	ML	$[(3.75,5.00,6.13), (2.50,5.00,7.13)]$	$[(0.38,0.50,0.61), (0.25,0.50,0.71)]$
C2	A1	M	M	H	MH	$[(5.00,6.50,7.63), (3.75,6.50,8.63)]$	$[(0.08,0.10,0.13), (0.07,0.10,0.17)]$
	A2	ML	L	M	ML	$[(1.75,3.00,4.50), (0.63,3.00,5.50)]$	$[(0.14,0.21,0.36), (0.11,0.21,1.00)]$
	A3	H	H	MH	MH	$[(6.50,8.00,8.75), (5.00,8.00,9.75)]$	$[(0.07,0.08,0.10), (0.06,0.08,0.13)]$
C3	A1	2	2	2	2	$[(2.00,2.00,2.00), (2.00,2.00,2.00)]$	$[(1.00,1.00,1.00), (1.00,1.00,1.00)]$
	A2	3.4	3.4	3.4	3.4	$[(3.40,3.40,3.40), (3.40,3.40,3.40)]$	$[(0.59,0.59,0.59), (0.59,0.59,0.59)]$
	A3	2.8	2.8	2.8	2.8	$[(2.80,2.80,2.80), (2.80,2.80,2.80)]$	$[(0.71,0.71,0.71), (0.71,0.71,0.71)]$
C4	A1	H	VH	VH	MH	$[(8.00,9.00,9.38), (6.75,9.00,9.88)]$	$[(0.81,0.91,0.95), (0.68,0.91,1.00)]$
	A2	VL	VL	L	M	$[(1.00,1.50,2.75), (0.63,1.50,3.50)]$	$[(0.10,0.15,0.28), (0.06,0.15,0.35)]$
	A3	H	MH	MH	H	$[(6.50,8.00,8.75), (5.00,8.00,9.75)]$	$[(0.66,0.81,0.89), (0.51,0.81,0.99)]$

C5	A1	ML	MH	MH	M	[(4.00,5.50,6.75),(2.88,5.50,8.00)]	[(0.40,0.55,0.68),(0.29,0.55,0.80)]
	A2	VH	VH	H	VH	[(9.00,9.75,9.88),(7.75,9.75,10.00)]	[(0.90,0.98,0.99),(0.78,0.98,1.00)]
	A3	VL	ML	L	M	[(1.38,2.25,3.63),(0.63,2.25,4.50)]	[(0.14,0.23,0.36),(0.06,0.23,0.45)]
C6	A1	L	L	M	VL	[(1.13,1.75,3.13),(0.63,1.75,4.00)]	[(0.20,0.36,0.56),0.16,0.36,1.00]
	A2	ML	M	M	M	[(3.00,4.50,6.00),(1.88,4.50,7.00)]	[(0.10,0.14,0.21),(0.09,0.14,0.33)]
	A3	H	H	MH	VL	[(7.50,8.75,9.25),(6.00,8.75,9.88)]	[(0.07,0.07,0.08),(0.06,0.07,0.10)]
C7	A1	M	L	ML	L	[(1.50,2.50,4.00),(0.63,2.50,5.00)]	[(0.16,0.25,0.42),(0.13,0.25,1.00)]
	A2	M	VH	M	ML	[(4.50,5.75,6.88),(3.38,5.75,7.63)]	[(0.09,0.11,0.14),(0.08,0.11,0.19)]
	A3	VH	VH	H	VH	[(9.00,9.75,9.88),(7.75,9.75,10.00)]	[(0.06,0.06,0.07),(0.06,0.06,0.08)]

It uses the anti-fuzzy operation and the ξ -channel table becomes table5.

Table5

Criteria	Alternatives	Defuzzification
C1	A1	0.2452
	A2	0.3853
	A3	0.3420
C2	A1	0.1311
	A2	0.4266
	A3	0.0088
C3	A1	1
	A2	0.5900
	A3	0.7100
C4	A1	0.4236
	A2	0.0858
	A3	0.5505

C5	A1	0.4314
	A2	0.2884
	A3	0.4547
C6	A1	0.5539
	A2	0.0722
	A3	0.0722
C7	A1	0.4721
	A2	0.0355
	A3	0.0023

All the steps of the proposed method in the mentioned example are presented in Table No. 7

	Q_i^1	Q_i^2	λ_i	Q_i
1.292992	0.065945	0.2679	0.3964	
0.803722	0.010197	0.5677	0.4607	
0.838809	0.000497	0.0023	0.0024	

The results of the interval fuzzy response method show that the second option has the first priority. After that, the first and third options are the next priorities.

Compared to Mokhtarian et al.'s (2014) article, the second and first options have been changed in the priority order of the options. In Mokhtarian et al.'s (2014) article, the first option was the most important option. Taking a close look at Mokhtarian's article, in which three comparisons between options were made with regard to reducing the uncertainty risk of the IVF-TOPSIS method, and in the first and second comparisons, the ranking was the same as the proposed model of the article, and finally, with the averaging of three comparisons, the ranking is different from the proposed ranking, and also if you look at the values of the fuzzy numbers for the options, you can see that the second option is a better situation than to the first and third options. In fact, this option has a lower amount than other options in most of the negative sub-criteria. In addition, in the positive sub-criteria, in most cases, it has a larger value than other options. In addition, due to the lack of defects of the IVF-TOPSIS method in Eshtiani's article [29], the best option is necessarily the closest solution to the ideal and the farthest option from the anti-ideal solution is not seen in this method. This research is more consistent with reality.

6.CONCLUSION

Decision-making is one of the most important issues of daily life that we always face and in today's economic world, choosing the best option according to the desired criteria leads to the survival of a company, since some issues have imprecise and vague numbers that Fuzzy numbers introduced by Zadeh are there are many classical methods for

ranking such problems. After fuzzy numbers, another type of fuzzy numbers was created, which became known as interval fuzzy numbers. In this research, methods for solving interval fuzzy multi-criteria decision-making problems were developed, which overcome the problems associated with the previous methods to some extent. Competitors all over the world are facing challenges in economic issues for products or services. In this case, in order to maintain the survival of companies, negative criteria should be minimized and positive criteria should be maximized. One of these important factors is choosing the location of facilities to reduce costs and obtaining profit is surplus. In such problems in the real world, most of the options and criteria are expressed qualitatively and fuzzy numbers. In this article, we proposed the IVF-WASPAS method to solve the option of choosing the place of alternatives and compared it with the method presented in the article of Mokhtarian et al. (2014) and Ashtiani's article in (2009). Most of the options are ranked.

For the future works, LINMAP and VIKOR methods can be used to solve the problem of choosing the location of facilities and IVF-MCDM problems.

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Dual approach for minimizing quasiconvex functions over closed convex cones

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Abstract:

One of the applications of Fenchel's duality theorem is in solving optimization problems that include minimization $f(x)$ with restrictions $x \in K$ in which f a lower semicontinuous convex function of \mathbb{R}^n and K a closed convex cone \mathbb{R}^n .

Also, this theorem has wide applications in linear and quadratic programming, and even in graph theory. The duality theorem establishes a duality relationship between the original problem and its dual problem, which in the dual problem is the minimization objective function and the inverse of the original function on the set K_+ . This article examines the generalization of the duality theorem to a non-convex function, which is used in the approximate duality theory.

According to the classic sandwich theorem, if a convex function is pointwise greater than or equal to a concave function and the proper regularity condition is satisfied, then there is an affine function between them.

Because Sandwich's theorem is not proved in quasi-convex analysis, it cannot be used to prove Fenchel's theorem. Therefore, in this paper, we use the generalized conjugate and discrete convexity approach to obtain abstract convex duality relations.

Keywords: Quasiconvex optimization, Fenchel Duality theory, Generalized conjugacy, Lipschitz function, Abstract convexity.

Introduction:

The optimization problem

$$\min_{x \in K} \{ -f^*(x^*) \} \quad (1-0)$$

is defined where f and K being a lower semicontinuous proper convex function on \mathbb{R}^n and a non-empty closed convex cone in \mathbb{R}^n , respectively.

The following dual problem related to the minimum optimization problem (1-0) is considered as follows:

$$\max_{x^* \in K^+} \{ -f^*(x^*) \}, \quad (2-0)$$

with

$$f^*(x^*) := \sup_{x \in \mathbb{R}^n} \{ \langle x, x^* \rangle - f(x) \}$$

and

$$K^+ := \{ x^* \in \mathbb{R}^n : \langle x, x^* \rangle \geq 0 \}.$$

One can apply Conditions on a problem such that the optimal primal and dual solutions are the same [24, Theorem 31.4]. In other words,

$$\inf_{x \in K} f(x) = \max_{x^* \in K^+} -f^*(x^*). \quad (3-0)$$

The duality

Duality theorem has applicability in linear and quadratic programming, and even in graph theory, as discussed in [24].

In this paper we consider the possibility of extending the duality relation (3-0) to a nonconvex setting, using generalized conjugacy. We present two applications to quasiconvex duality theory.

Generalized conjugacy was originally proposed in [20]. Its use in nonconvex duality theory, using essentially the same approach as in this paper, was pioneered in [1,5,9]. As for quasiconvex conjugation has followed the initial works [2,3,8,11,12,21]. Quasiconvex duality theory studied by many researchers such as [2,4,7,8,10,12,22]. Besides, detailed studies of quasiconvex duality based on generalized conjugacy methods can be found in [13,23].

The standard approach to the duality relation (3-0) is based on Fenchel's Duality Theorem. The classical

sandwich theorem states that if a convex function is pointwise greater than or equal to a concave function and a mild regularity condition holds, then there is an affine function between them. In a generalized conjugacy setting, an analogue of this theorem is equivalent to the validity of a sandwich type theorem, as proved in [16]. Since there is no sandwich theorem in quasiconvex analysis, there is no hope to obtain an analogue of Fenchel's Duality Theorem in this context. Therefore, to obtain quasiconvex analogues of the duality relation, in this paper we aim to follow the generalized conjugacy approach.

This paper is organized as follows in three sections. Section one includes definitions and preliminaries related to basic definitions of convex, quasiconvex, Fenchel, Duality and conjugacy. In the second section, we develop an abstract

duality scheme, based on generalized conjugacy. Our first quasiconvex duality results are presented in section 3.

1 Definitions and preliminary concepts

In this section, the basic and essential concepts required are presented. It is defined that $\mathbb{R} = (-\infty, +\infty)$, $\mathbb{R}^+ = [0, +\infty)$, $\overline{\mathbb{R}} = (-\infty, +\infty)$ and I is an interval of \mathbb{R} .

Definition 1.1. Suppose that τ is a topology on a vector space X , such that

- 1) Every point of X is a closed set.
- 2) Operations of the vector space according to the topology τ are continuous.

Therefore, τ is called a vector topology on X and X is called a topological vector space.

Definition 1.2. Let S be a topological space. A collection Γ of the neighborhoods of a point $p \in S$ is called a local basis in p if every neighborhood of p contains members of Γ .

Definition 1.3. Let X be a topological vector space with topology τ . X is called locally convex if there exists a local basis \mathcal{B} such that its members are convex sets. Thus, the topology defined on \mathcal{B} is called locally convex topology.

Definition 1.4. Let X be a vector space over the field F (real or complex). The map

$$\|\cdot\|: X \rightarrow \mathbb{R}$$

is called a norm on X , if for each x and y of X and α of F the following conditions hold:

- a) $\|x\| = 0$ iff $x = 0$ and $\|x\| \geq 0$;
- b) $\|\alpha x\| = |\alpha| \|x\|$;
- c) $\|x + y\| \leq \|x\| + \|y\|$;

The symbol $\|x\|$ is called (norm x), and a vector space X with the norm $\|\cdot\|$ is called a norm space, which is denoted by the symbol $(X, \|\cdot\|)$.

Definition 1.5. The closed ball with center x and radius r , is defined as follows:

$$B_r(x) = \{y : \|y - x\| \leq r\}.$$

Definition 1.6. Let X be a norm space. The set consisting of continuous linear functions on X , denoted by X^* , is called the dual space of X .

Definition 1.7. Let $f: I \rightarrow \mathbb{R}$,

- a) The function f is called quasiconvex, if $f(\lambda a + (1 - \lambda)b) \leq f(b)$, for every $a, b \in I$ with $f(a) \leq f(b)$ and every $\lambda \in (0,1)$. In other words,

$$f(\lambda a + (1 - \lambda)b) \leq \max \{f(a), f(b)\}.$$

for each $a, b \in I$ and each $\lambda \in [0,1]$,

- b) The function f is said to be strictly quasiconvex, if the inequality in (a) holds.

c) The function f is called quasiconcave if $-f$ is quasiconvex.

Definition 1.8. The function $f: X \rightarrow \mathbb{R}$, where X is a locally convex real topological vector space, is called equally quasiconvex if for every $\lambda \in \mathbb{R}$, the set λ -subsurface

$$S_\lambda(f) = \{x \in X : f(x) \leq \lambda\}.$$

be equally convex, that is, the intersection of open subspaces (see [6]),

The function f is quasiconvex if and only if the set $S_\lambda(f)$ is convex for every $\lambda \in \mathbb{R}$.

Definition 1.9. Suppose that X is a norm space and K is a nonempty convex subset of X . A set K is called equally convex if for every $x_0 \in X \setminus K$, there exists $x^* \in X^*$ such that

$$\langle x - x_0, x^* \rangle < 0, \forall x \in K.$$

Therefore, K is equally convex if and only if it can be written as a union of open subspaces.

Definition 1.10. Suppose that $f: I \rightarrow \mathbb{R}$, f is called Lipschitz function with respect to $I_0 \subset I$, whenever there exists $k > 0$ such that for every $x, y \in I_0$,

$$|f(x) - f(y)| \leq k|x - y|.$$

Definition 1.11. Suppose that X is a norm vector space and $f: X \rightarrow \mathbb{R}$, the conjugate (Fenchel conjugate) of f is the function $f^*: X^* \rightarrow \mathbb{R}$, which is defined as follows

$$f^*(x^*) = \sup\{\langle x, x^* \rangle - f(x) | x \in X\}.$$

Definition 1.12. [26] Let f and g be functions of $X \rightarrow \mathbb{R} \cup \{+\infty\}$. Then,

$$(f + g)^* = f^* + g^*.$$

Definition 1.13. Let V be a vector space. The affine function on V is $x \mapsto f(x) + \alpha$ where $f: V \rightarrow \mathbb{R}$ is linear and $\alpha \in \mathbb{R}$.

Definition 1.14. [26] Suppose that X is a norm vector space and X^* is the dual of X , if $f: X \rightarrow \mathbb{R}$ and $x_0 \in X$ such that $f(x_0) \in \mathbb{R}$, then

a) Let $x_0^* \in X^*$, so the point x_0^* is called the subgradient of f whenever

$$f(x) \geq f(x_0) + \langle x - x_0, x_0^* \rangle, (x \in X)$$

b) The set of subgradients of f at the point x_0 is called the subdifferential of f at the point x_0 and is denoted by the symbol $\partial f(x_0)$. Also, $\partial f(x_0)$ is a convex subset of X^* . Moreover, the function f is subdifferentiable at x_0 if $\partial f(x_0) \neq \emptyset$.

If f is not finite at x , then $\partial f(x) = \emptyset$ is defined.

c) The subdifferential of f is a set function $\partial f: x \mapsto \partial f(x)$ from X to X^* .

d) $\text{dom}(\partial f) = \{x \in X | \partial f(x) \neq \emptyset\}$.

Example 1.15. [26] A) Suppose that $f: (a, b) \rightarrow \mathbb{R}$ is convex, then f is subdifferentiable in every $c \in (a, b)$ and we have:

$$\partial f(c) = [f'_-(c), f'_+(c)],$$

where $f'_+(c)$ and $f'_-(c)$ are the right and left derivatives of f at point c , respectively.

b) Consider the function: $\mathbb{R} \rightarrow \mathbb{R}$ as follows:

$$f(x) = \begin{cases} -\sqrt{1-x^2} & , \text{ if } |x| \leq 1 \\ +\infty & , \text{ if } |x| > 1 \end{cases}$$

Thus, f is a proper convex function that is subdifferentiable on $(-1, +1)$. Also,

$-1, +1 \in \text{dom}(f)$, but f is not subdifferentiable at -1 or $+1$.

c) Suppose $X = \mathbb{R}^n$ and consider Euclidean norm on \mathbb{R}^n . Suppose $f(x) = \|x\|$. Therefore, f is not differentiable at 0 but f is subdifferentiable at 0 and

$$\partial f(0) = \{x^* \in \mathbb{R}^n : \langle y, x^* \rangle \leq \|y\|, \forall y \in \mathbb{R}^n\}.$$

Then, $\partial f(0)$ is a closed unit sphere

$$\{x \in \mathbb{R}^n : \|x\| \leq 1\}$$

In the following example, the generalization of the concepts of subgradient and subdifferential are defined in the discrete case.

Example 16. 1. [25] Suppose that X is an arbitrary nonempty set, $f: X \rightarrow \mathbb{R}$ is a function defined on the set X and H is a set of functions defined on X , such as $h: X \rightarrow \mathbb{R}^n$.

a) The supported set of the function f with respect to H is denoted by $\text{supp}(f, H)$ and is defined as follows:

$$\text{supp}(f, H) := \{ h \in H : h(x) \leq f(x), \forall x \in X \}.$$

b) The function f is called abstract convex with respect to H (H -convex), if there exists a set $\Delta \subseteq H$ such that for $x \in X$,

$$f(x) = \sup_{h \in \Delta} h(x).$$

c) The function $h \in H$ is called a subgradient H of the function f at the point $x_0 \in \text{dom} f$, if for each $x \in X$,

$$f(x) - f(x_0) \geq h(x) - h(x_0).$$

The set of all H -subgradients of the function f at the point x_0 , which is denoted by $\partial_H f(x_0)$, is called the H -subdifferential of the function f at the point x_0 and is defined as follows:

$$\partial_H f(x_0) = \{ h \in H \mid h(x_0) \in \mathbb{R}, f(x) - f(x_0) \geq h(x) - h(x_0), \forall x \in X \}.$$

The function f is H -convex if and only if for $x \in X$,

$$f(x) = \sup_{h \in \text{supp}(f, H)} h(x).$$

Example 1.17. Consider H as the set of quadratic functions $h: \mathbb{R} \rightarrow \mathbb{R}$ with the $h(x) = ax^2 + bx + c$, where $a < 0$ and $a, b, c \in \mathbb{R}$. Then the function $f: \mathbb{R} \rightarrow \mathbb{R}$ with

$$f(x) = -x^2 + \frac{1}{(1+x^2)}.$$

is an H -convex function. Indeed, for every $x \in \mathbb{R}$,

$$f(x) = \sup \{ h(x) \mid h \in \text{supp}(f, H) \},$$

where

$$\text{supp}(f, H) = \{ h \in H \mid h(x) = ax^2 \leq -x^2 + \frac{1}{(1+x^2)}, a \leq -1 \}.$$

Definition 1.18. [25] Let X be a vector space. A set $K \subseteq X$ is called a cone if for each $x \in K$ and each $\alpha \geq 0$, we have: $\alpha x \in K$. (Note that $0 \in K$)

Definition 1.19. Suppose that X is a topological space, the function $f: X \rightarrow \mathbb{R}$ is called upper semicontinuous if the set

$$\{ x \in X \mid f(x) < \alpha \}$$

be open for every $\alpha \in \mathbb{R}$.

Let X be a topological space, the function $f: X \rightarrow \mathbb{R}$ is called lower semicontinuous if the set $\{ x \in X \mid f(x) > \alpha \}$ is open for every $\alpha \in \mathbb{R}$.

Definition 1.20. Suppose that X is a norm space and $f: X \rightarrow \mathbb{R}$, the function f is said to be positive homogeneous, whenever for every $x \in X$ and every $\lambda \geq 0$, $f(\lambda x) = \lambda f(x)$.

Definition 1.21. Let X be a vector space on \mathbb{R} . A subset $A \subset X$ is called affine if we have for every $x, y \in A$ and every $\lambda \in \mathbb{R}$:

$$\lambda x + (1 - \lambda)y \in A.$$

Definition 1.22. Let X be the vector topological space and $A \subset X$. The interior of A with respect to the subset $\text{aff}(A)$ (with relative topology) is called the relative interior of A and it is represented by the symbol $\text{ri}(A)$.

Definition 1.23. Let X be a linear topological space and $A \subset X$, the relative interior of A is the interior of A that is a subset of $\text{aff}(A)$ (with relative topology) and is denoted by the symbol $\text{ri}(A)$.

Theorem 1.24. [26] (Fenchell's duality) Suppose that X is a norm vector space, f is a convex function on X and g is a concave function on X . If

a) There exists a point in $\text{dom}(f) \cap \text{dom}(g)$ such that f or g is continuous;

b) $X = \mathbb{R}^n$ and $\text{ri}(\text{dom}(f)) \cap \text{ri}(\text{dom}(g)) \neq \emptyset$.

Then,

$$\inf_{x \in X} \{ f(x) - g(x) \} = \max_{x^* \in X^*} \{ g^*(x^*) - f^*(x^*) \}.$$

Theorem 1.25. [14] (Fenchel's duality) Suppose that $f: \mathbb{R}^n \rightarrow \bar{\mathbb{R}}$ is a convex function and $g: \mathbb{R}^n \rightarrow \bar{\mathbb{R}}$ is a concave function such that $g \leq f$ and $f^{-1}(\mathbb{R}) \cap g^{-1}(\mathbb{R}) \neq \emptyset$, then there exists a function $\psi \in \Phi$ such that $g \leq \psi \leq f$ where Φ is the set of finite value functions.

Definition 1.26. Let X be a norm space, the function $f: K \subset X \rightarrow \bar{\mathbb{R}}$ is called α -Holder with constant N , whenever

$$f(x_1) - f(x_2) \leq N \|x_1 - x_2\|^\alpha,$$

for every $x_1, x_2 \in K$.

Definition 1.27. Let (M_1, d_1) and (M_2, d_2) be metric spaces and $\alpha \in \mathbb{R}$. Then, the mapping $f: M_1 \rightarrow M_2$ is called α -Holder continuous if and only if there exists $L \in \mathbb{R}$ such that

$$d_2(f(x), f(y)) \leq L(d_1(x, y))^\alpha$$

for every $x, y \in M_1$.

Definition 1.28. Let X be a vector topological space on \mathbb{R} and $A \subset X$. The support function A is the conjugate δ_A^* of the indicator function δ_A , which is defined as follows:

$$\begin{aligned}\delta_A^*(x^*) &= \sup_{x \in X} \{ \langle x, x^* \rangle - \delta_A(x) \} \\ &= \sup_{x \in A} \langle x, x^* \rangle, \quad (x^* \in X^*)\end{aligned}$$

A binary $(X, +)$ is monoid whenever X is a set and $+$ is a binary operation on X (zero is the neutral member of X). If X has the property of commutative with respect to the operation $+$, we say it is commutative. You can refer to [10] for more study of tequar and its applications.

2 A generalized conjugacy duality scheme

In this section, an optimization problem is considered, which is expressed by the classical convex standard method, its dual, and its optimal solutions are discussed.

In the case that there is no duality gap between the original problem and its dual, results are presented that examine the optimal solutions for one of the dual problems in terms of the optimal solution of the other problem. Also, the duality theorems presented in the previous section are expressed in the much more general case of monoids.

Notation 2.1. If X is a norm space, the conjugate of the function $f: X \rightarrow \bar{\mathbb{R}}$ is the function $f^*: X^* \rightarrow \bar{\mathbb{R}}$, which is defined as follows:

$$f^*(x^*) = \sup_{x \in X} \{ \langle x, x^* \rangle - f(x) \}, \quad (x^* \in X^*),$$

And the conjugate of the function $g: X^* \rightarrow \bar{\mathbb{R}}$ is the function $g^*: X \rightarrow \bar{\mathbb{R}}$, which is defined as follows:

$$g^*(x) = \sup_{x^* \in X^*} \{ \langle x, x^* \rangle - g(x^*) \}, \quad (x \in X).$$

Now, a generalization of it is given below:

Let $(X, +)$ be a monoid with commutative property and zero neutral element, consider Y to be an arbitrary nonempty set. Let $c: X \times Y \rightarrow \mathbb{R} \cup \{-\infty\}$ be a binary function and

$$f: X \rightarrow \mathbb{R} \cup \{+\infty\}$$

be The dual c -conjugate $f, f^c: Y \rightarrow \bar{\mathbb{R}}$ is defined as follows:

$$f^c(y) = \sup_{x \in X} \{ c(x, y) - f(x) \}, \quad (y \in Y).$$

Also, the c' -conjugate of the function $g: Y \rightarrow \bar{\mathbb{R}}$ is the function $g^{c'}: X \rightarrow \bar{\mathbb{R}}$ and is defined as:

$$g^{c'}(x) = \sup_{y \in Y} \{ c(x, y) - g(y) \},$$

with the convention that $-\infty - (-\infty) = -\infty$. Note that this definition corresponds to the binary function $c': Y \times X \rightarrow \bar{\mathbb{R}}$ where $c'(y, x) = c(x, y)$.

Functions of the form $x \mapsto c(x, y) - \beta \in \bar{\mathbb{R}}$ where $x \in X, y \in Y$ and $\beta \in \bar{\mathbb{R}}$ are called c -fundamental functions and also c' -fundamental functions are functions of the form $y \mapsto c(x, y) - \beta \in \bar{\mathbb{R}}$ where $y \in Y, x \in X$ and $\beta \in \bar{\mathbb{R}}$ are denoted by symbols ϕ_c and $\phi_{c'}$, respectively.

Definition 2. 2. [17] Let X be a norm vector space and $f: X \rightarrow \bar{\mathbb{R}}$. f at $x_0 \in X$ is c -subdifferentiable whenever $f(x_0) \in \mathbb{R}$ and $y_0 \in Y$ exist such that $c(x_0, y_0) \in \mathbb{R}$

and

$$f(x) - f(x_0) \geq c(x, y_0) - c(x_0, y_0), (x \in X)$$

where y_0 is called c -subgradient of f at the point x_0 ; The set of all c -subgradients of f at the point x_0 is called the c -subdifferential of f at x_0 and is represented by $\partial_c f(x_0)$.

Proposition 2. 3. [17] Suppose that $f: X \rightarrow \mathbb{R}$, $g: Y \rightarrow \mathbb{R}$, $x \in X$ and $y \in Y$. Then

$$a) f^c(y) \geq c(x, y) - f(x) \text{ and } g^{c'}(x) \geq c(x, y) - g(y).$$

$$b) f^{cc'} = f^c \text{ and } g^{c'cc'} = g^{c'}.$$

c) f^c and $g^{c'}$ are $\phi_{c'}$ -convex and ϕ_c -convex, respectively, which ϕ_c -convex function f with $f^{cc'}$ and $\phi_{c'}$ -convex of the function g corresponds to $g^{c'c}$.

Result 2.4. [17] The function $f: X \rightarrow \mathbb{R}$, is ϕ_c -convex if and only if it coincides with c -conjugative of second order $f^{cc'}$ and the function $g: Y \rightarrow \mathbb{R}$, is $\phi_{c'}$ -convex if and only if it coincides with c' -conjugate of second order $g^{c'c}$. So the function f in $x_0 \in X$ is ϕ_c -convex if $f^{cc'}(x_0) = f(x_0)$ and the function g in $y_0 \in Y$ is $\phi_{c'}$ -convex if $g^{c'c}(y_0) = g(y_0)$.

Example 2. 5. [17] Suppose that $X = Y = \mathbb{R}^n$, $0 < \alpha \leq 1$, $N > 0$ and $c: X \times Y \rightarrow \mathbb{R}$ is defined as follows:

$$c(x, y) = -N \|x - y\|^\alpha.$$

Then the function $f: X \rightarrow \mathbb{R}$ is ϕ_c -convex if and only if it is α -Holder continuous with constant N .

Example 2. 6. [17] Suppose X is a topological space, Y is a set, $c: X \times Y \rightarrow \mathbb{R}$ such that for every $(x_0, y_0, \eta) \in X \times Y \times \mathbb{R}$ and every neighborhood N of x_0 , $y' \in Y$ and neighborhood $N' \subseteq N$ exists so that

$$c(x, y') - c(x_0, y') \leq c(x, y) + \eta, (x \in X \setminus N'),$$

and

$$c(x, y') - c(x_0, y') \leq 0, (x \in X).$$

Then $f: X \rightarrow \mathbb{R} \cup \{+\infty\}$ is ϕ_c -convex if and only if it is lower semicontinuous.

Furthermore, if X is a Hilbert space and $Y = \mathbb{R}_+ \times X$, then the function $c: X \times Y \rightarrow \mathbb{R}$ is defined by

$$c(x, (p, y)) = -p \|x - y\|^2$$

Example 2. 7. [19] Let X be a norm space with dual X^* , $0 < \alpha \leq 1$ and $Y = B^*(0; N) \times \mathbb{R}$ where $B^*(0; N)$ is a closed unit sphere in X^* with radius $N > 0$. The function $c: X \times Y \rightarrow \mathbb{R}$ is defined as follows:

$$c(x, (\omega, k)) = \min\{-(k - \omega(x))^\alpha, 0\} + k.$$

By Considering $t^\alpha = -\infty$, if $t < \cdot$ and $\alpha \neq 1$, then $f: X \rightarrow \mathbb{R}$ is ϕ_c -convex if and only if it is quasiconvex and α -Holder continuous with constant N^α .

Let

$$Y_0 = \{y \in Y : c(0, y) > -\infty\}$$

Given $K \subset X$ such that $0 \in K$, we consider the set

$$K^c = \{y \in Y_0 : c(x, y) \leq c(x + k, y), \forall x \in X, \forall k \in K\}.$$

We consider the following assumptions:

A1 $Y_0 \neq \emptyset$.

A2 For every $y \in Y_0 \setminus K^c$, there exists $z_y \in K^c$ such that

$$c(x, z_y) - c(0, z_y) \leq \sup_{u \in X: x \in u+K} c(u, y) - c(0, y), \forall x \in X. \quad (1.2)$$

A3 The restriction of f to K is not identically $+\infty$.

Notice that, under Assumption A2, Assumption A1 is equivalent to $K^c \neq \emptyset$

Because, if $Y_0 \neq \emptyset$, then there exists $y_0 \in Y_0$ such that $c(0, y_0) > -\infty$. Now, if $y_0 \in K^c$, then $K^c \neq \emptyset$ and if $y_0 \notin K^c$, then $y_0 \in Y_0 \setminus K^c$ and according to assumption (A2), $z_{y_0} \in K^c$ exists. So $K^c \neq \emptyset$.

Conversely, if $K^c \neq \emptyset$, according to the definition of K^c there is a member $y \in Y_0$, so $Y_0 \neq \emptyset$.

Since in the relation (1.2) the right side of the classical convex condition is equal to $+\infty$, then assumption (A2) is valid.

In this setting, we consider the following problem, which we will denote by $P(f,K)$,

$$\min_{x \in K} f(x)$$

Adapting to our setting a standard procedure in classical convex duality, in order to associate a dual to this problem, for $u \in X$ it is natural to consider the perturbed problem $P(f, K, u)$, defined by

$$\min_{x \in u+K} f(x)$$

In a special case, $P(f,K,0) = P(f,K)$. The corresponding perturbation function $P: X \rightarrow \mathbb{R}$ is given by

$$p(u) = \inf_{x \in u+K} f(x) \quad (2.2)$$

Note that $P(u)$ is the optimal value of problem $P(f,K,u)$; in particular, $P(0)$ is the optimal value of $P(f,K)$. According to classical generalized convex duality theory, under Assumption A1 a dual problem to $P(f,K)$ is the unconstrained problem

$$\max_{y \in Y_0} c(0,y) - p^c(y). \quad (3.2)$$

For more details, you can refer to Section 3, [17]. Clearly, the optimal value of this dual problem is $P^{cc'}(0)$.

Theorem 2.8. Let f, K, c, K^c and p be as above. Then

1. For every $y \in K^c$,

$$p^c(y) = f^c(y). \quad (4.2)$$

Duality for quasiconvex minimization...

2. Under assumption A2,

$$\sup_{y \in Y_0} \{c(0,y) - p^c(y)\} = \sup_{y \in K^c} \{c(0,y) - f^c(y)\}.$$

Moreover, the following statements hold:

a) If the supremum in the left hand side is attained, then the supremum in the right hand side is attained, too.

b) If the supremum in the left hand side is attained at $y \in K^c$, then the supremum in the right hand side is attained at y , too.

c) If the supremum in the right hand side is attained at y , then the supremum in the left hand side is attained at y , too.

Proof (1) According to the definition of c -conjugate and the assumption $y \in K^c$, we have:

$$\begin{aligned} p^c(y) &= \sup_{u \in X} \{c(u,y) - p(u)\} = \sup_{u \in X} \{c(u,y) - \inf_{x \in u+K} f(x)\} \\ &= \sup_{u \in X} \{c(u,y) + \sup_{x \in u+K} (-f(x))\} = \sup_{u \in X} \sup_{x \in u+K} \{c(u,y) - f(x)\} \\ &= \sup_{x, u \in X} \sup_{x \in u+K} \{c(u,y) - f(x)\} = \sup_{x \in X} \sup_{u \in X, x \in u+K} \{c(u,y) - f(x)\} \\ &= \sup_{x \in X} \{c(x,y) - f(x)\} = f^c(y). \end{aligned} \quad (6.2)$$

(2) Under assumption (2), relation (4.2) and the definition of c -conjugate, for each $y \in Y_0 \setminus K^c$, we have:

$$\begin{aligned} c(0,y) - p^c(y) &= c(0,y) - \sup_{u \in X} \{c(u,y) - p(u)\} = c(0,y) - \sup_{u \in X} \{c(u,y) - \inf_{x \in u+K} f(x)\} \\ &= c(0,y) - \sup_{x \in X} \sup_{u: x \in u+K} \{c(u,y) - f(x)\} \leq c(0,z_y) - \sup_{x \in X} \{c(x,z_y) - f(x)\} \\ &= c(0,z_y) - f^c(z_y) \leq c(0,z_y) - \inf_{z \in K^c} f^c(z) \\ &= c(0,z_y) - \inf_{z \in K^c} p^c(z) = \sup_{y \in K^c} \{c(0,y) - p^c(y)\}. \end{aligned}$$

So,

$$\sup_{y \in Y_0 \setminus K^c} \{c(0,y) - p^c(y)\} \leq \sup_{y \in K^c} \{c(0,y) - p^c(y)\}.$$

We conclude that

$$\begin{aligned} \sup_{y \in Y_0} \{c(0, y) - p^c(y)\} &= \sup_{y \in K^c} \{c(0, y) - p^c(y)\} \\ &= \sup_{y \in K^c} \{c(0, y) - f^c(y)\}. \end{aligned}$$

Statement b) is an easy consequence of (4.2) and (5.2). Because if $y \in Y_0$, then $y \in K^c$ or $y \in Y_0 \setminus K^c$, which in the case of $y \in Y_0 \setminus K^c$, according to assumption (2), $z_y \in K^c$ exists.

If the supremum in the left hand side of (5.2) is attained at $y \in Y_0 \setminus K^c$, then, by (5.2) and (6.2), the supremum in the right hand side is attained at z_y . This, together with b), proves a).

Statement c) immediately follows from (4.2) and (5.2). \square

In view of Theorem 2.8, the dual problem (2.3) can be reformulated as

$$\begin{aligned} \max_{\text{s.t. } y \in K^c} \{c(0, y) - f^c(y)\}. \end{aligned} \quad (7.2)$$

Indeed, both (2.3) and (2.7) have the same optimal values, (2.7) has an optimal solution whenever (2.3) has some, and every optimal solution to (2.7) is an optimal solution to (2.3), too. We will denote problem (2.7) by $D(f, K)$.

Theorem 2.9. Let f , K , c , K^c and p be as above. Then, under assumption A2, if x is an optimal solution to $P(f, K)$ and there is no duality gap between $P(f, K)$ and $D(f, K)$, one has

$$f^{cc'}(x) = f(x).$$

Proof. We have

$$\begin{aligned} f^{cc'}(x) &= \sup_{y \in Y} \{c(x, y) - f^c(y)\} \geq \sup_{y \in K^c} \{c(x, y) - f^c(y)\} \\ &\geq \sup_{y \in K^c} \{c(0, y) - f^c(y)\} = f(x). \end{aligned}$$

And on the other hand, according to the definition of $f^c(y)$, we have:

$$f^c(y) \geq c(x, y) - f(x).$$

So

$$c(x, y) - f^c(y) \leq f(x).$$

Therefore

$$\sup_{y \in Y} \{c(x, y) - f^c(y)\} \leq f(x).$$

In conclusion

$$f^{cc'}(x) \leq f(x). \square$$

Now, below you can see a generalization of the previous proposition:

Proposition 10. 2. [17] Suppose $f: X \rightarrow \mathbb{R}$, $x_0 \in X$ and $y_0 \in Y$. If $c(x_0, y_0) \in \mathbb{R}$, then

- $f(x_0) + f^c(y_0) = c(x_0, y_0)$ iff $y_0 \in \partial_{-c} f(x_0)$
- $x_0 \in \partial_{c'} f^c(y_0)$ iff $y_0 \in \partial_c f^{cc'}(x_0)$
- if $\partial_c f(x_0) \neq \emptyset$, then f is ϕ_c -convex in x_0 .
- if f is ϕ_c -convex in x_0 , then $\partial_c f^{cc'}(x_0) = \partial_c f(x_0)$.
- $y_0 \in \partial_c f(x_0)$ iff $x_0 \in \partial_{c'} f^c(y_0)$.

Proposition 2.11. [17] According to proposition 2.10, for ϕ_c -convex functions $f: X \rightarrow \mathbb{R}$ the inverse of c -subdifferential of $\phi_c f$ is $\partial_{c'} f^c$ and for each $x_0 \in X$ and $y_0 \in X$, we have: $y_0 \in \partial_c f(x_0)$ if and only if $x_0 \in \partial_{c'} f^c(y)$.

Proposition 12. 2. [17] Suppose $X = Y = \{1, 2\}$ and $c: X \times Y \rightarrow \mathbb{R}$ is defined as follows:

$$c(i, j) = \begin{cases} 1 & \text{if } i = j \\ 0 & \text{if } i \neq j \end{cases}$$

Consider the functions $f_1, f_2, f_3 : X \rightarrow \mathbb{R}$ so that

$$f_1(1) = f_1(2) = 1, f_3(1) = 1, f_2(2) = 0, f_2(1) = 1, f_3(2) = \frac{3}{2}.$$

Therefore, for each $x \in \{1, 2\}$, we have:

$$f_1(x) = \max_{f_0} \{ \{ c(x, "1"), c(x, "2") \} \}$$

$$f_1(x) = \max\{ c(x, 1), c(x, 2) \}$$

and

$$f_2(x) = \max\{ c(x, 1), c(x, 2) - 1 \}$$

and

$$f_3(x) = \max\{ c(x, 1), c(x, 2) + \frac{1}{2} \}.$$

Since all three functions are ϕ_c -convex, their c -subdifferentials are obtained as follows:

$$\partial_c f_1(x) = \{x\}, \partial_c f_2(1) = \{1\}, \partial_c f_2(2) = Y, \partial_c f_3(x) = \{x\}, (x \in X)$$

In the following, the optimal solutions for one of the dual problems $P(f, K)$ and $D(f, K)$ are characterized according to the optimal solution of the other problem.

Theorem 2.13. Let f, K, c and K^c be as above. Then, under assumptions A2 and A3, if x is an optimal solution to $P(f, K)$ and $y \in K^c$, then

y is an optimal solution to $D(f, K)$ and

there is no duality gap between $P(f, K)$ and $D(f, K)$

$$\Leftrightarrow y \in \partial_c f(x) \text{ and } c(x, y) = c(0, y)$$

Proof. If y is an optimal solution to $D(f, K)$ and there is no duality gap between $P(f, K)$ and $P(f, K)$, then

$$f(x) + f^c(y) = c(0, y) \leq c(x, y).$$

On the other hand, according to the definition of $f^c(x)$, we have: $f(x) \geq c(x, y) - f^c(y)$. so

$$f(x) + f^c(y) \geq c(x, y).$$

Therefore, $f(x) + f^c(y) = c(x, y) = c(0, y)$, according to proposition (2-10) part a), the first equality means that $y \in \partial_c f(x)$.

Conversely, if $y \in \partial_c f(x)$ and $c(x, y) = c(0, y)$. Then,

$$c(0, y) - f^c(y) = c(x, y) - f^c(y) = f(x).$$

Which proves that y is an optimal solution to $D(f, K)$ and there is no duality gap between $P(f, K)$ and $D(f, K)$. \square

Theorem 2.14. Let f, K, c and K^c be as above. Then, under assumptions A2 and A3, if y is an optimal solution to $D(f, K)$ and $x \in K$, then x is an optimal solution to $P(f, K)$ and there is no duality gap between $P(f, K)$ and $D(f, K)$

\Leftrightarrow

$$c(x, y) = c(0, y), x \in \partial_{c'} f^c(y), f^{cc'}(x) = f(x).$$

Proof. We proceed very similarly to the proof of Theorem 2.13. If x is an optimal solution to $P(f, K)$ and there is no duality gap between $P(f, K)$ and $D(f, K)$, then

$$f(x) + f^c(y) = c(0, y) \leq c(x, y),$$

And on the other hand, according to the definition of $f^{cc'}(x)$, we have: $f^{cc'}(x) + f^c(y) \geq c(x, y)$ and

$$f^{cc'}(x) + f^c(y) \leq f(x) + f^c(y).$$

in conclusion

$$f^{cc'}(x) + f^c(y) = f(x) + f^c(y) = c(x, y) = c(0, y).$$

Therefore, according to proposition (2. 10), $x \in \partial_{c'} f^c(y)$ and furthermore according to theorem (2.9), it is obtained that $f^{cc'}(x) = f(x)$.

Conversely, if $c(x, y) = c(0, y)$, $x \in \partial_{c'} f^c(y)$ and $f^{cc'}(x) = f(x)$, then

$$f(x) = f^{cc'}(x) = c(x, y) - f^c(y) = c(0, y) - f^c(y).$$

which proves that x is an optimal solution to $P(f, K)$ and there is no duality gap between $P(f, K)$ and $D(f, K)$.

Theorem 2.15. [17] Let X be a topological space, for each $h: X \rightarrow \overline{\mathbb{R}}$, the following propositions are equivalent:

- a) h is ϕ_c -convex.
- b) for $f \in \overline{\mathbb{R}}^X$, $\inf_{x \in X} \{f(x) - h(x)\} = \inf_{x \in X} \{f(x) - h^{cc'}(x)\}$.
- c) for $f \in \overline{\mathbb{R}}^X$, $\inf_{x \in X} \{f(x) - h(x)\} = \inf_{y \in Y} \{h^c(y) - f^c(y)\}$.
- d) for $f \in \overline{\mathbb{R}}^X$, $\inf_{x \in X} \{f(x) - h(x)\} = \inf_{x \in X} \{f^{cc'}(x) - h^{cc'}(x)\}$.
- e) for $f \in \overline{\mathbb{R}}^X$, $\inf_{x \in X} \{f(x) - h(x)\} = \inf_{x \in X} \{f^{cc'}(x) - h(x)\}$.

Remark 2.16. Since the objective function of $D(f, K)$ is $f^c = f^{cc'c}$, this dual problem coincides with $D(f^{cc'}, K)$; therefore $P(f, K)$ and $P(f^{cc'}, K)$ share the same dual problem. Thus, for duality matters, it is natural to assume that $f = f^{cc'}$.

following the terminology of [5], that f is ϕ_c -convex, with

$$\phi_c := \{c(0, y) - \beta : y \in Y, \beta \in \overline{\mathbb{R}}\}.$$

Note that in the convex case, if X is a locally convex real topological space and $Y = X^*$. Also, suppose that the binary function $c: X \times X^* \rightarrow \mathbb{R}$ is the dual product, that is, $\langle \cdot, \cdot \rangle$. It is easy to see that in this case, $Y_0 = X^*$ and for a closed convex cone $K \subset X$ and a function $f: X \rightarrow \mathbb{R} \cup \{+\infty\}$ under assumption (A3), it is obtained that

$$K^c = K^+ := \{x^* \in X^* : \langle x, x^* \rangle \geq 0, \forall x \in X\} \quad (8.2)$$

and $f^c = f^*$. As stated earlier, assumption (A2) is clearly established in the classical convex case. Therefore, the dual problem $D(f, K)$ becomes the classical convex dual problem.

Also, in general, it is not possible to reach the primal problem from the dual problem. Since the dual problem does not have a structure similar to the original problem, then no dual problem is related to it, or in other words, the dual problem is not defined in the general framework of this research.

3 Duality for quasiconvex functions

In this section, we introduce the concept of duality in the case that the objective functions are quasiconvex. Then, we consider the objective function to be finite-valued, quasiconvex and Lipscheets and examine its properties. Also, when there is no duality gap between the main problem and its dual, it is studied and results are presented.

Let X be a locally convex real topological vector space with dual X^* . We denote by $\langle \cdot, \cdot \rangle : X \times X^* \rightarrow \mathbb{R}$ the duality product. We set X^* and consider the coupling function $c: X \times Y \rightarrow \mathbb{R} \cup \{-\infty\}$ defined by

$$c(x, x^*) = \begin{cases} 0 & \text{if } \langle x, x^* \rangle \geq 0 \\ -\infty & \text{if this is not the case} \end{cases} \quad (1.3)$$

The c -conjugate of $f: X \rightarrow \overline{\mathbb{R}}$ is the function $f^c: X^* \rightarrow \overline{\mathbb{R}}$ given by

$$f^c(x^*) = \inf_{\langle x, x^* \rangle \geq 0} f(x). \quad (2.3)$$

the c' -conjugate of $g: X^* \rightarrow \overline{\mathbb{R}}$ is the function $g^c: X \rightarrow \overline{\mathbb{R}}$ given by

$$g^c(x) = \inf_{\langle x, x^* \rangle \geq 0} g(x^*). \quad (3.3)$$

On combining (3.2) with (3.3), one obtains the following expression for the second c -conjugate:

$$f^{cc'}(x) = \sup_{\langle x, x^* \rangle \geq 0} \inf_{\langle x', x^* \rangle \geq 0} f(x').$$

For $f: X \rightarrow \overline{\mathbb{R}}$ and $\lambda \in \mathbb{R}$, we denote by

$$\hat{S}_\lambda(f) := \{x \in X : f(x) < \lambda\}.$$

the strict λ -sublevel set of f .

Proposition 3.1. [17] If function $f: X \rightarrow \overline{\mathbb{R}}$ is c -convex at $x_0 \in X$, then

$$\partial_c f^{cc'}(x_0) = \partial_c f(x_0).$$

Notation 3.2. [19] The function $f: X \rightarrow \overline{\mathbb{R}}$ is ϕ_c -convex at $x_0 \in X$ if and only if

$$f^{cc'}(x_0) = f(x_0).$$

Proposition 3.3. [19] A function $f: X \rightarrow \mathbb{R}$ is c -convex at $x_0 \in X$ if and only if for every $\lambda < f(x_0)$ there exists $x^* \in X^*$ such that $\langle x_0, x^* \rangle \geq 0$ and $\langle x, x^* \rangle < 0$ for every $x \in S_\lambda(f)$.

Theorem 3. 4. [17] A function f is ϕ_c -convex if and only if it is evenly quasiconvex.

Notation 3.5. In the classical case, let f be a convex function on X . In this case, the function f has a global minimum at $x_0 \in X$ if and only if

$$f(x) \geq f(x_0) + \langle x - x_0, 0 \rangle.$$

For every $x \in X$, then the function f has a global minimum at x_0 if and only if $0 \in \partial f(x_0)$.

Corollary 3.6. [19] A function $f: X \rightarrow \mathbb{R}$ is c -convex if and only if it is evenly quasiconvex and positively homogeneous of degree zero and has a global maximum at 0.

Corollary 3.6. About c -subdifferentials, for $x \in f^{-1}(\mathbb{R})$ and $x^* \in X^*$ such that $\langle x, x^* \rangle \geq 0$, the following equivalence results:

$$x^* \in \partial_c f(x) \Leftrightarrow f(x) = \inf_{\langle x', x^* \rangle \geq 0} f(x'). \quad (4.3)$$

Proof. If $f(x) = \inf_{\langle x', x^* \rangle \geq 0} f(x')$, then $f^c(x^*) = -f(x)$ and $\langle x, x^* \rangle \geq 0$,

So according to the definition of function c , $c(x, x^*) = 0$. As a result $f(x) + f^c(x^*) = c(x, x^*)$ and according to proposition (2.10), $x^* \in \partial_c f(x)$.

Conversely, if $x^* \in \partial_c f(x)$, then according to proposition (2.10), we have: $f(x) + f^c(x^*) = c(x, x^*)$ and because $\langle x, x^* \rangle \geq 0$. So $\langle x, x^* \rangle = 0$. then

$$f(x) = -f^c(x^*) = -\left(-\inf_{\langle x', x^* \rangle \geq 0} f(x')\right) = \inf_{\langle x', x^* \rangle \geq 0} f(x'). \quad \square$$

Let $K \subset X$ be a closed convex cone. Then, it is clear that the relation (2.8) holds. Also, assumption (A2) holds, because for $x^* \in X^* \setminus K^+$, it is easy to see that

$$\sup_{u \in X: x \in u+K} c(u, y) = 0.$$

Let $f: X \rightarrow \mathbb{R} \cup \{+\infty\}$ and consider the problem $P(f, K)$:

$$\begin{array}{ll} \min & f(x) \\ \text{s.t.} & x \in K \end{array}$$

According to Notation (2.16) and the Corollary (3.6), it can be assumed that the objective function f is identically quasiconvex, positive homogeneous of degree zero and has a global maximum at zero.

The following result is obtained from theorem (2.13).

Theorem 3.8. Let $f: X \rightarrow \mathbb{R} \cup \{+\infty\}$, $K \subset X$ be a closed convex cone, and

$$c: X \times X^* \rightarrow \mathbb{R} \cup \{+\infty\}$$

be the coupling function defined by (1.3). Then, under Assumption

A3, if x_0 is an optimal solution to $P(f, K)$ and $x^* \in K^+$, then x^* is an optimal solution to $D(f, K)$ and there is no duality gap between $P(f, K)$ and $D(f, K)$

$$\Leftrightarrow \langle x_0, x^* \rangle \geq 0 \text{ and}$$

$$f(x_0) = \min_{\langle x, x^* \rangle \geq 0} f(x).$$

proof. Suppose x_0 is the optimal solution of $P(f, K)$, x^* is the optimal solution of $D(f, K)$ and there is no dual gap between them, then $f(x) = c(0, x^*) - f^c(x^*)$. On the other hand, $f^c(x^*) = \inf_{\langle x, x^* \rangle \geq 0} f(x)$ and $c(0, x^*) = 0$. Therefore

$$f(x_0) = \min_{\langle x, x^* \rangle \geq 0} f(x).$$

Conversely, if x_0 is the optimal solution of $P(f, K)$ and $f(x_0) = \min_{\langle x, x^* \rangle \geq 0} f(x)$, so $f(x) = c(0, x^*) - f^c(x^*)$, which means that there is no duality gap between $P(f, K)$ and $D(f, K)$. \square

In the following, you will see the theorem (2.14) in the quasiconvex state. According to the Corollary (3.6) and Notation (3.2), the conditions of the theorem (2.14) are that f is identically quasiconvex, homogeneous from degree zero and has a global maximum at zero. It is shown that here the condition of f being quasiconvex is sufficient.

Theorem 3.9. Let f , K and c be as in Theorem 3.8, and assume that f is evenly quasiconvex. Then, under Assumption A3, if x_0^* is an optimal solution to $D(f, K)$ and $x_0 \in K$, then x_0 is an optimal solution to $P(f, K)$ and there is no duality

gap between $P(f, K)$ and $D(f, K)$

$$\Leftrightarrow \langle x_0, x_0^* \rangle \geq 0 \text{ and}$$

$$f(x_0) = \min_{\langle x, x_0^* \rangle \geq 0} f(x).$$

Proof. Let $\tilde{f}: X \times \mathbb{R} \rightarrow \mathbb{R} \cup \{+\infty\}$ be defined by

$$\tilde{f}(x, t) := \begin{cases} f\left(\frac{x}{t}\right) & t > 0 \\ +\infty & t \leq 0 \end{cases} \text{ If}$$

It is not difficult to prove that f is evenly quasiconvex, positively homogeneous of

degree zero, and has a global maximum at 0. Let $\tilde{K} := K \times \mathbb{R}_+$. Clearly, $P(f, K)$

and $P(\tilde{f}, \tilde{K})$ have the same optimal value, and x_0 is an optimal solution to $P(f, K)$

if and only if $(x_0, 1)$ is an optimal solution to $P(\tilde{f}, \tilde{K})$. On the other hand, since $\tilde{K}^+ = K^+ \times \mathbb{R}_+$, the optimal value $D(\tilde{f}, \tilde{K})$ is

$$\begin{aligned} \sup_{x^* \in K^+} \sup_{t^* \geq 0} \inf_{t > 0, \langle x, x^* \rangle + tt^* \geq 0} f\left(\frac{x}{t}\right) &= \sup_{x^* \in K^+} \sup_{t^* \geq 0} \inf_{\langle x', x^* \rangle + t^* \geq 0} f(x') \\ &= \sup_{x^* \in K^+} \inf_{\langle x', x^* \rangle \geq 0} f(x'). \end{aligned}$$

so it coincides with that of $D(f, K)$. Moreover $(x_0^*, 0)$ is an optimal solution to

$D(\tilde{f}, \tilde{K})$. Hence, there is no duality gap between $P(f, K)$ and $D(f, K)$ if and only

if the same holds for $P(\tilde{f}, \tilde{K})$ and $D(\tilde{f}, \tilde{K})$. Therefore, by Theorem 3.8 and Corollary 3.6, x_0 is an optimal solution to $P(f, K)$ and there is no duality gap between $P(f, K)$ and $D(f, K)$ if and only if $\langle x_0, x_0^* \rangle \geq 0$ and

$$f(x_0) = \min_{t > 0, \langle x, x_0^* \rangle \geq 0} f\left(\frac{x}{t}\right).$$

As

$$\min_{t > 0, \langle x, x_0^* \rangle \geq 0} f\left(\frac{x}{t}\right) = \min_{\langle x, x_0^* \rangle \geq 0} f(x).$$

We obtain

$$f(x_0) = \min_{\langle x, x_0^* \rangle \geq 0} f(x). \square$$

We next present a sufficient condition for strong duality to hold.

Theorem 3.10. [17] The optimal value of the dual problem $D(f, K)$ is not greater than the optimal value of $P(f, K)$, they coincide if and only if the perturbation function p is ϕ_c -convex. In this case, if the optimal value is finite, the optimal solution $D(f, K)$ is $\partial_c p(u)$.

Theorem 11. 3. Assume that f, K and c are defined similarly to theorem (3.8) and consider f to be quasiconvex and upper semicontinuous. Then there is no duality gap between $P(f, K)$ and $D(f, K)$ and $D(f, K)$ has an optimal solution.

Now we consider quasiconvex functions with Lipschets condition

Put $Y := B^*(0; N) \times \mathbb{R}$ and the binary function $c: X \times Y \rightarrow \mathbb{R}$ is defined as follows:

$$c(x, (x^*, \alpha)) := \min\{\langle x, x^* \rangle, \alpha\} \quad (5.3)$$

And the c -conjugate function of $f: X \rightarrow \mathbb{R}$ is the function $f^c: B^*(0; N) \times \mathbb{R} \rightarrow \mathbb{R}$, which is as follows:

$$f^c(x^*, \alpha) = \sup_{x \in X} \{\min\{\langle x, x^* \rangle, \alpha\} - f(x)\}. \quad (6.3)$$

And the c' -dual function $g: B^*(0; N) \times \mathbb{R} \rightarrow \mathbb{R}$ is the function $g^c: X \rightarrow \mathbb{R} \rightarrow \mathbb{R}$ which is as follows:

$$g^c(x) = \sup_{\langle x^*, \alpha \rangle \in B^*(0; N) \times \mathbb{R}} \{\min\{\langle x, x^* \rangle, \alpha\} - g(x^*, \alpha)\}.$$

For the second-order c -dual function f , we have:

$$\begin{aligned} f^{cc'}(x) &= \sup_{\langle x^*, \alpha \rangle \in B^*(0; N) \times \mathbb{R}} \{\min\{\langle x, x^* \rangle, \alpha\} - f^c(x^*, \alpha)\} \\ &= \sup_{\langle x^*, \alpha \rangle \in B^*(0; N) \times \mathbb{R}} \{\min\{\langle x, x^* \rangle, \alpha\} - \sup_{x' \in X} \{\min\{\langle x', x^* \rangle, \alpha\} - f(x')\}\} \end{aligned}$$

$$\begin{aligned}
 &= \sup_{\langle x^*, \alpha \rangle \in B^*(0; N) \times \mathbb{R}} \{ \min\{ \langle x, x^* \rangle, \alpha \} + \inf_{x' \in X} \{ -\min\{ \langle x', x^* \rangle, \alpha \} - f(x') \} \} \\
 &= \sup_{\langle x^*, \alpha \rangle \in B^*(0; N) \times \mathbb{R}} \{ \min\{ \langle x, x^* \rangle, \alpha \} + \inf_{x' \in X} \{ f(x') - \min\{ \langle x', x^* \rangle, \alpha \} \} \} \\
 &= \sup_{\langle x^*, \alpha \rangle \in B^*(0; N) \times \mathbb{R}} \{ \min\{ \langle x, x^* \rangle, \alpha \} \\
 &\quad + \inf_{x' \in X} \{ f(x') - \min\{ \langle x' - x, x^* \rangle, 0 \} \} \}.
 \end{aligned}$$

In conclusion

$$f^{cc'}(x) = \max_{\langle x^*, \alpha \rangle \in B^*(0; N) \times \mathbb{R}} \{ \min\{ \langle x, x^* \rangle, \alpha \} + \inf_{x' \in X} \{ f(x') - \min\{ \langle x' - x, x^* \rangle, 0 \} \} \}.$$

In the following proposition, the ϕ_c -convex function is characterized.

Proposition 3.12. [15,19] The function $f: X \rightarrow \bar{\mathbb{R}}$ is ϕ_c -convex if and only if $f \equiv \pm\infty$ or finite-valued, quasiconvex and Lipsheets with constant N .

For the c -subdifferential of the function $f: X \rightarrow \bar{\mathbb{R}}$ in $\bar{x} \in X$, the following equivalence results for $(x^*, \alpha) \in B^*(0; N) \times \mathbb{R}$ is presented.

$$(x^*, \alpha) \in \partial_c f(\bar{x}) \Leftrightarrow f(x) \geq f(\bar{x}) + \min\{ \langle x, x^* \rangle, \alpha \} - \min\{ \langle \bar{x}, x^* \rangle, \alpha \}, \forall x \in X.$$

Notation 3.13 [19] The lower subdifferential of the function $f: X \rightarrow \bar{\mathbb{R}}$ in $\bar{x} \in X$ is the following set:

$$\partial^- f(\bar{x}) = \{ x^* \in X^* : f(x) \geq f(\bar{x}) + \langle x - \bar{x}, x^* \rangle, \forall x \in \hat{S}_{f(\bar{x})}(f) \}.$$

Let $K \subset X$ be a closed convex cone. In this case

$$K^c = (K^+ \cap B^*(0; N)) \times \mathbb{R}.$$

If assumption (A2) holds, since for each $x^* \in X^* \setminus K^+$, $\alpha \in \mathbb{R}$ and $x \in X$, we have:

$$c(x, (0, \alpha)) - c(0, (0, \alpha)) = \min\{0, \alpha\} - \min\{0, \alpha\} = 0.$$

and

$$\begin{aligned}
 &\sup_{u \in X: x \in u + K} c(x, (x^*, \alpha)) - c(0, (x^*, \alpha)) \\
 &= \sup_{k \in K} \min\{ \langle x - k, x^* \rangle, \alpha \} - \min\{0, \alpha\} = \alpha - \min\{0, \alpha\} = \max\{\alpha, 0\},
 \end{aligned}$$

to prove

$$\sup_{k \in K} \min\{ \langle x - k, x^* \rangle, \alpha \} = \alpha$$

consider $k_0 \in K$ such that $\langle k_0, x^* \rangle < 0$. We see that for $\lambda \geq \frac{\langle x, x^* \rangle - \alpha}{\langle k_0, x^* \rangle}$,

$$\sup_{k \in K} \min\{ \langle x - k, x^* \rangle, \alpha \} \geq \min\{ \langle x - \lambda k_0, x^* \rangle, \alpha \} = \alpha.$$

Suppose $f: X \rightarrow \mathbb{R} \cup \{+\infty\}$ and consider the problem $P(f, K)$:

$$\begin{aligned} &\min f(x) \\ &\text{s.t. } x \in K \end{aligned}$$

According to the relation (3.6) and the duality scheme in the previous section, its dual problem is $D(f, K)$, i.e.

$$\begin{aligned} &\max \\ &\text{s.t. } x^* \in K^+ \cap B^*(0; N) \end{aligned} \min\{0, \alpha\} - f^c(x^*, \alpha)$$

This special case of $D(f, K)$ is denoted by $D_0(f, K)$.

According to Notation (2.16), proposition (2.13) and assumption (A3), it can be assumed that the function f is finite-valued, quasiconvex and Lipsheets with constant N .

Remark 3.14. According to the proposition (2.11), for the function ϕ_c -convex f , and $x \in X$ and $y \in Y$, it can be obtained that

$$x \in \partial_{c'} f^c(y) \Leftrightarrow y \in \partial_c f(x).$$

In below two clear results of theorems (2.13) and (2.14) are presented. Note that the previous remark is also used for the second result.

Theorem 3.15. Let $f: X \rightarrow \mathbb{R} \cup \{+\infty\}$ and $K \subset X$ be a closed convex cone. Consider binary function

$c: X \times (B^*(0; N) \times \mathbb{R}) \rightarrow \mathbb{R}$. If under assumption (A3), x is the optimal solution of $P(f, K)$ and $(x^*, \alpha) \in (K^+ \cap B^*(0; N)) \times \mathbb{R}$, Then (x^*, α) is the optimal solution of $D(f, K)$ and there is no duality gap between $P(f, K)$ and $D(f, K)$ if and only if $(x^*, \alpha) \in \partial_c f(x)$.

Theorem 3.16. Suppose f , K and c are defined as in theorem (3.15) and consider f finite-valued, quasiconvex and Lipschitz with constant N . In this case, under assumption (A3), if (x^*, α) is the optimal solution of $D(f, K)$ and $x \in K$, then x is the optimal solution of $P(f, K)$ and There is no duality gap between $P(f, K)$ and $D(f, K)$ if and only if $(x^*, \alpha) \in \partial_c f(x)$.

Suppose $C = X$, $D = X^* \times \mathbb{R}$ and $h_\alpha: C \times D \rightarrow \mathbb{R}$ with $\alpha \in (0, 1]$ whose conjugate function is defined as follows:

$$h_\alpha(x, (\omega, k)) = \min \{ -(k - \omega(x))^\alpha, 0 \} + k.$$

The h_α -conjugate of the function $f: X \rightarrow \mathbb{R}$ and $g: X^* \times \mathbb{R} \rightarrow \mathbb{R}$ are the functions $f^{h_\alpha}: X^* \times \mathbb{R} \rightarrow \mathbb{R}$ and $g^{h_\alpha}: X \rightarrow \mathbb{R}$ which are defined as follows:

$$f^{h_\alpha}(\omega, k) = \sup_{x \in X} \min \{ -(k - \omega(x))^\alpha, 0 \} + k - f(x)$$

and

$$g^{h_\alpha}(x) = \sup_{\omega \in X^*, k \in \mathbb{R}} \{ \min \{ -(k - \omega(x))^\alpha, 0 \} + k - g(\omega, k) \}.$$

Fundamental functions on X are of the form

$$\min \{ -(k - \omega)^\alpha, 0 \} + \mu, \omega \in X^*, k \in \mathbb{R}, \mu \in \mathbb{R}$$

Now, suppose $D_N = B^*(0; N) \times \mathbb{R}$ and $\alpha \in (0, 1]$, the binary function $h_{\alpha, N}: X \times D_N \rightarrow \mathbb{R}$ is defined as follows:

$$h_{\alpha, N}(x, (\omega, k)) = \min \{ -(k - \omega(x))^\alpha, 0 \} + k.$$

Therefore $h_{\alpha, N} = h_\alpha \mid X \times D_N$ and $h_{\alpha, N}$ -dual of the function $f: X \rightarrow \mathbb{R}$ and $g: D_N \rightarrow \mathbb{R}$, are functions $f^{h_{\alpha, N}}: D_N \rightarrow \mathbb{R}$ and $g^{h_{\alpha, N}}: X \rightarrow \mathbb{R}$, which are defined as follows:

$$f^{h_{\alpha, N}}(\omega, k) = \sup_{x \in X} \{ \min \{ -(k - \omega(x))^\alpha, 0 \} + k - f(x) \}$$

and

$$g^{h_{\alpha, N}}(x) = \sup_{\omega \in B^*(0; N), k \in \mathbb{R}} \{ \min \{ -(k - \omega(x))^\alpha, 0 \} + k - g(\omega, k) \}.$$

Lemma 3.17. [17] Let $\alpha \in (0, 1]$ and $a, b \in \mathbb{R}$ such that $a, b \geq 0$. Therefore,

$$(a + b)^\alpha \leq a^\alpha + b^\alpha.$$

Proposition 3.18. If $f: X \rightarrow \mathbb{R}$, then for all $x_0 \in X$,

$$f^{h_{\alpha, N}}(x_0) = \sup_{\omega \in X^*} \inf_{x \in X} \max \{ (\omega(x_0 - x))^\alpha + f(x), f(x) \}.$$

Proof. By definition h_α -conjugate, we have

$$\begin{aligned} f^{h_{\alpha, N}}(x_0) &= \sup_{(\omega, k) \in D} \{ \min \{ -(k - \omega(x_0))^\alpha, 0 \} + k - f^{h_\alpha}(\omega, k) \} \\ &= \sup_{(\omega, k) \in D} \{ \min \{ -(k - \omega(x_0))^\alpha, 0 \} + k \} \\ &\quad - \sup_{x \in X} \{ \min \{ -(k - \omega(x))^\alpha, 0 \} + k - f(x) \} \\ &= \sup_{(\omega, k) \in D} \inf_{x \in X} \{ \min \{ -(k - \omega(x_0))^\alpha, 0 \} \} \\ &\quad - \min \{ -(k - \omega(x))^\alpha, 0 \} + f(x) \}. \end{aligned}$$

It is sufficient to show that for all $x \in X$, the statement

$$\min \{ -(k - \omega(x_0))^\alpha, 0 \} - \min \{ -(k - \omega(x))^\alpha, 0 \}$$

as a function of x , has the maximum value at $k = \omega(x_0)$. i.e.,

$$\min \{ -(k - \omega(x_0))^\alpha, 0 \} - \min \{ -(k - \omega(x))^\alpha, 0 \} \leq \max \{ (\omega(x_0 - x))^\alpha, 0 \}. \quad (7.3)$$

If $k \leq \omega(x)$, since the first term is less than or equal to zero, the inequality (3.7) holds, if $k \geq \omega(x)$ and $\omega(x_0)$ is not between these two values, then (3.7) holds, because the function t^α is ascending. Finally, if $k \geq \omega(x_0) \geq \omega(x)$, inequality (3.7) follows from lemma (3.17). \square

Definition 3.19. Suppose $\alpha \in (0,1]$ and $K \subset X$ is a convex set and $f: K \rightarrow \overline{\mathbb{R}}$, is called α -l.s.d in $x_0 \in K$. If $f(x_0) \in \mathbb{R}$, $\omega \in X^*$ exists such that

$$f(x) \geq f(x_0) - (\omega(x_0 - x))^\alpha.$$

For every $x \in K$ with the condition $f(x) < f(x_0)$.

The continuous linear function ω is called the α -lower subgradient of f at the point x_0 . The set of lower α -subgradients of f at the point x_0 is called the lower α -subdifferential of f at the point x_0 and is denoted by the symbol $\partial_\alpha^- f(x_0)$. Let f be α -l. s.d if it has a lower α -subgradient at all points of K .

Proposition 3.20. Suppose $f: X \rightarrow \overline{\mathbb{R}}$ and $x_0 \in X$ such that $f(x_0) \in \mathbb{R}$. Then for every $\omega \in X^*$, the following propositions are equivalent:

a) There exists a member $k \in \mathbb{R}$ such that $(\omega, k) \in \partial_{h_\alpha} f(x_0)$.

b) $(\omega, \omega(x_0)) \in \partial_{h_\alpha} f(x_0)$.

c) $\omega \in \partial_\alpha^- f(x_0)$.

Proof. (a) \Rightarrow (c) Let $(\omega, k) \in \partial_{h_\alpha} f(x_0)$ and $x \in X$ where $f(x) < f(x_0)$. Then,

$$\begin{aligned} 0 &> f(x) - f(x_0) \\ &\geq \min\{-(k - \omega(x))^\alpha, 0\} - \min\{-(k - \omega(x_0))^\alpha, 0\} \\ &\geq \min\{-(k - \omega(x))^\alpha, 0\}. \end{aligned} \quad (8.3)$$

So, $f(x) - f(x_0) \geq -(k - \omega(x))^\alpha$. If $k \leq \omega(x_0)$,

$$(\omega(x_0 - x))^\alpha \geq (k - \omega(x))^\alpha.$$

By (3.8), we conclude that $f(x) - f(x_0) \geq -(\omega(x_0 - x))^\alpha$ and this completes the proof. If $k > \omega(x_0)$, by relation (3.8), we have

$$\begin{aligned} f(x) - f(x_0) &\geq \min\{-(k - \omega(x))^\alpha, 0\} + (k - \omega(x_0))^\alpha \\ &= -(k - \omega(x))^\alpha + (k - \omega(x_0))^\alpha. \end{aligned} \quad 9.3$$

Equality in (3.9) because of $f(x) < f(x_0)$ holds. Similarly, it follows that $\omega(x_0 - x) > 0$. Now, consider $a = k - \omega(x_0)$ and $b = \omega(x_0 - x)$, according to lemma (3.17) it is obtained that $f(x) - f(x_0) \geq -(\omega(x_0 - x))^\alpha$. So $\omega \in \partial_\alpha^- f(x_0)$.

(c) \Rightarrow (b) Let $x \in X$ be. If $f(x) < f(x_0)$ and $\omega \in \partial_\alpha^- f(x_0)$, then

$$\begin{aligned} f(x) &\geq f(x_0) - (\omega(x_0 - x))^\alpha \\ &\geq f(x_0) + \min\{-(\omega(x_0 - x))^\alpha, 0\}. \end{aligned}$$

If $f(x) \geq f(x_0)$, then

$$f(x) \geq f(x_0) \geq f(x_0) + \min\{-(\omega(x_0 - x))^\alpha, 0\}.$$

Since $h_\alpha(x, (\omega, \omega(x_0))) - h_\alpha(x_0, (\omega, \omega(x_0))) = \min\{-(\omega(x_0 - x))^\alpha, 0\}$, we obtain $(\omega, \omega(x_0)) \in \partial_{h_\alpha} f(x_0)$. \square

Note that the bounded lower α -subdifferential functions are denoted by the symbol α -b. l. s.d.

Definition 3.21. Let X be a norm space and $f: K \subset X \rightarrow \overline{\mathbb{R}}$, let f be α -l. b. s. d say whenever $N > 0$ exists such that for every $x \in K$, there exists $\omega^* \in \partial_\alpha^- f(x)$ such that $\|\omega^*\| \leq N$. Let the constant N be α -b. l. s. d is called the limit of f .

Theorem 3.22. [19] Suppose $f: X \rightarrow \overline{\mathbb{R}}$ is quasiconvex and α -Holder with constant N , then f , α -b. l. s.d with α -b. l. s.d is the limit of $N^{\frac{1}{\alpha}}$.

Corollary 3.23. [19] Let $f: X \rightarrow \overline{\mathbb{R}}$. In this case, the function α -b. l.s.d with α -b. l.s.d is the bound of N if and only if it is quasiconvex and α -Holder with constant N^α .

Theorem 3.24. Suppose $f: X \rightarrow \overline{\mathbb{R}}$, then the following statements are equivalent:

a) $f \in B_N^\alpha(X)$.

b) $f(X) \subset \mathbb{R}$, f is quasiconvex and α -Holder with constant N^α or $f \equiv \pm\infty$;

c) f , α -b. l.s.d with α -b. l.s.d is the limit of N or $f \equiv \pm\infty$.

Proposition 3.25. Suppose $f: X \rightarrow \overline{\mathbb{R}}$. In this case, for each $x_0 \in X$,

$$f^{h_{\alpha,N}h_{\alpha,N}}(x_0) = \max_{x_0 \in B^*(0;N)} \inf_{x \in X} \max\{(\omega(x_0 - x))^\alpha + f(x), f(x)\}.$$

Proof. With a method similar to Proposition (3.20), a formula is obtained which is a maxim instead of the maximum expression, it is shown that this maxim when $f^{h_{\alpha,N}h_{\alpha,N}}$ is finite, at every point $\omega_0 \in \partial_\alpha^- f^{h_{\alpha,N}h_{\alpha,N}}(x_0) \cap B^*(0; N)$ is obtained. If $f^{h_{\alpha,N}h_{\alpha,N}}$ is not finite, then there is two cases: In the first case, suppose $\omega_0 \in \partial_\alpha^- f^{h_{\alpha,N}h_{\alpha,N}}(x_0) \cap B^*(0; N)$, for every $x \in S_{f^{h_{\alpha,N}h_{\alpha,N}}}(x_0)$ ($f^{h_{\alpha,N}h_{\alpha,N}}$), it is obtained that

$$f^{h_{\alpha,N}h_{\alpha,N}}(x) \geq f^{h_{\alpha,N}h_{\alpha,N}}(x_0) - (\omega_0(x_0 - x))^\alpha.$$

Then, for all $x \in X$,

$$\begin{aligned} f^{h_{\alpha,N}h_{\alpha,N}}(x) &\geq \min\{f^{h_{\alpha,N}h_{\alpha,N}}(x_0), f^{h_{\alpha,N}h_{\alpha,N}}(x_0) - (\omega_0(x_0 - x))^\alpha\} \\ &= f^{h_{\alpha,N}h_{\alpha,N}}(x_0) + \min\{0, -(\omega_0(x_0 - x))^\alpha\} \end{aligned}$$

or

$$\max\{(\omega_0(x_0 - x))^\alpha + f^{h_{\alpha,N}h_{\alpha,N}}(x), f^{h_{\alpha,N}h_{\alpha,N}}(x)\} \geq f^{h_{\alpha,N}h_{\alpha,N}}(x_0).$$

So

$$\begin{aligned} f^{h_{\alpha,N}h_{\alpha,N}}(x_0) &= \sup_{\omega_0 \in B^*(0, N)} \inf_{x \in X} \max\{(\omega(x_0 - x))^\alpha + f(x), f(x)\} \\ &\geq \inf_{x \in X} \max\{(\omega_0(x_0 - x))^\alpha + f(x), f(x)\} \\ &\geq \inf_{x \in X} \max\{(\omega(x_0 - x))^\alpha + f^{h_{\alpha,N}h_{\alpha,N}}(x), f^{h_{\alpha,N}h_{\alpha,N}}(x)\} \\ &\geq f^{h_{\alpha,N}h_{\alpha,N}}(x_0). \end{aligned}$$

Finally

$$f^{h_{\alpha,N},h_{\alpha,N}}(x_0) = \inf_{x \in X} \max\{(\omega_0(x_0 - x))^\alpha + f^{h_{\alpha,N},h_{\alpha,N}}(x), f^{h_{\alpha,N},h_{\alpha,N}}(x)\}.$$

In the second case, if $f^{h_{\alpha,N},h_{\alpha,N}}$ is not finite, then according to theorem (3.24) we can conclude that $f^{h_{\alpha,N},h_{\alpha,N}} \equiv +\infty$ or $f^{h_{\alpha,N},h_{\alpha,N}} \equiv -\infty$ which in every two cases, a maximum is obtained in every $\omega \in B^*(0; N)$ (note that $f^{h_{\alpha,N},h_{\alpha,N}} \equiv +\infty$ only if $f \equiv +\infty$). □

According to theorem (3.10) if there is no duality gap between $P(f,K)$ and $D(f,K)$, then the optimal solution $P(f,K)$, is $\partial_c p(0)$. Therefore, according to proposition (3.20), if (x^*, α) is the optimal solution of $D(f,K)$, then $(x^*, 0)$ is also the optimal solution. Therefore, under the assumption of the existence of an optimal solution for $P(f,K)$ by placing $\alpha := 0$ in the definition of $D(f,K)$, we have the following simplified dual problem, which is denoted with $D_0(f,K)$:

$$\begin{aligned} &\max_{x^* \in K^+ \cap B^*(0;N)} f^c(x^*, 0) \\ \text{s.t. } &x^* \in K^+ \cap B^*(0;N) \end{aligned}$$

Remark 3.26. From theorem (3.15) and putting $x^* = 0$ in proposition 4· 8 in [15], it can be obtained that $\alpha(0) = -\infty$ and $\beta(0) = +\infty$.

Theorem 3.27. Let f, K and c be as in Theorem 3.15. Then, under Assumption A3, if x is an optimal solution to $P(f,K)$ and $x^* \in K^+ \cap B^*(0; N)$. Then, x^* is an optimal solution to $D_0(f,K)$ and there is no duality gap between $P(f,K)$ and $D(f,K)$ iff $x^* \in \partial^- f(x)$

Theorem 3.28. Let f, K and c be as in Theorem 3.15, and assume that f is finite valued, quasiconvex, and Lipschitz with constant N . Then, under Assumption A3, if x^* is an optimal solution to $D_0(f,K)$ and $x \in K$, then x is an optimal solution to $P(f,K)$ and there is no duality gap between $P(f,K)$ and $D_0(f,K)$ iff $x^* \in \partial^- f(x)$.

Our next theorem states that strong duality holds if the objective function is quasiconvex and Lipschitz with constant N .

Theorem 3.15. Let f, K and c be as in Theorem 3.29, and assume that f is finite valued, quasiconvex, and Lipschitz with constant N . Then there is no duality gap between $P(f,K)$ and $D(f,K)$, and $D(f,K)$ has an optimal solution.

Proof. By

$$\hat{S}_\lambda(p) = \hat{S}_\lambda(f) - K, \quad (10.3)$$

the strict sublevel sets of the perturbation function p are convex, which implies that p is quasiconvex. Moreover, since for each $k \in K$ the function $f(\cdot + k)$ is Lipschitz with constant N , from the equality $p = \inf_{k \in K} f(\cdot + k)$ it follows

that p is either Lipschitz with constant N , too, or identically equal to $-\infty$. In the case $p \equiv -\infty$, the conclusion in the statement is obvious. In the first case, by Corollary 3. and Theorem 3.10, we have $\partial_c p(u) \neq \emptyset$ for every $u \in X$; in particular, $\partial_c p(0) \neq \emptyset$, which, by [17, Theorem 6.7], concludes the proof. \square

Corollary 3.30. Let f , K and c be as in Theorem 3.15, and assume that f is finite valued, quasiconvex and Lipschitz with constant N , and $P(f,K)$ has an optimal solution. Then there is no duality gap between $P(f,K)$ and $D_0(f,K)$, and $D_0(f,K)$ has an optimal solution.

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Electrical and Optical Properties of CsPbI₂Br and its Variants: A Comparative Review

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Abstract:

This comprehensive review article examines the electrical and optical properties, synthesis methods, stability considerations, comparative analysis, challenges, and recent advancements of CsPbI₂Br and its variants. Through an extensive literature survey conducted using databases such as Scopus, Web of Science, and Google Scholar, coupled with a systematic organization of topics, we provide a holistic overview of the current state-of-the-art in CsPbI₂Br research. The review begins with an introduction outlining the importance of CsPbI₂Br in optoelectronic applications and the motivation behind conducting this study. We then describe the methodology used to gather and analyze relevant literature, including the selection criteria for articles and databases searched. Topics discussed include structural characteristics, variants of CsPbI₂Br, synthesis methods (such as chemical vapor deposition, solution-processed methods, and other techniques), comparison of synthesis methods, electrical and optical properties, stability and degradation mechanisms, comparative analysis with other halide perovskites, research trends, and recent advancements. Finally, the conclusion highlights the immense potential of CsPbI₂Br in various optoelectronic applications, despite challenges such as stability issues and material processing complexities. We emphasize recent advancements, including stabilization strategies, defect engineering, tandem cell integration, scalable fabrication methods, and emerging applications, as key drivers propelling CsPbI₂Br research toward practical implementation.

Keywords: CsPbI₂Br, perovskite, optoelectronics, synthesis methods, stability, electrical properties, optical properties

1- Introduction

Halide perovskites have emerged as a promising class of materials for a variety of optoelectronic applications, including solar cells, light-emitting diodes (LEDs), and photodetectors. Among these, cesium lead halide perovskites, particularly CsPbI₂Br, have gained significant attention due to their favorable thermal and phase stability, as well as their impressive optoelectronic properties (Xiang & Tress, 2019);(Zhou et al., 2018).

CsPbI₂Br crystallizes in a tetragonal phase at room temperature, which transitions to a cubic phase at higher temperatures (Liu et al., 2024). This structural stability is crucial for maintaining consistent optoelectronic performance. Variants of CsPbI₂Br can be synthesized by partially substituting iodine or bromine with other halides (e.g., Cl or F) or by doping with other cations (e.g., MA⁺, FA⁺) to tune the material's properties (Zeng et al., 2019). For example, mixed-halide perovskites like CsPbI₂-xBr_x have shown tunable bandgaps and enhanced stability (Akman et al., 2023).

The synthesis of high-quality CsPbI₂Br films is critical for their application in devices. Solution-processed methods such as spin coating are commonly used due to their simplicity and scalability (Chen et al., 2019). Solvent engineering, where the choice of solvents and additives influences film morphology, has been shown to improve film quality and device performance (Haider et al., 2024). Chemical vapor deposition (CVD) and vapor-assisted solution processes are also employed to achieve highly crystalline films with fewer defects. A comparative study indicates that CVD methods

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generally produce films with superior uniformity and fewer pinholes compared to solution-processed methods (Faheem et al., 2019).

The electrical properties of CsPbI₂Br are characterized by high charge carrier mobility and low defect densities. Intrinsic conductivity is primarily governed by the perovskite's composition and crystallinity (Song et al., 2022). Doping with elements like Sn or Ge can further enhance conductivity by introducing shallow defect states (Akman et al., 2023). Charge carrier mobility in CsPbI₂Br films has been reported to be in the range of 10-20 cm²/Vs, which is comparable to other high-performance perovskites like MAPbI₃ (Jin et al., 2021). Methods such as time-resolved photoluminescence (TRPL) and space-charge-limited current (SCLC) measurements are commonly used to evaluate carrier mobility and trap densities (Tailor et al., 2021).

CsPbI₂Br exhibits strong absorption in the visible region with an absorption coefficient exceeding 10⁵ cm⁻¹ (Ghaithan et al., 2021). Its bandgap, around 1.9 eV, is suitable for single-junction solar cells and other optoelectronic applications (Tian et al., 2022). Alloying and compositional tuning allow for bandgap engineering, facilitating the design of materials with tailored optical properties for specific applications (Ullah, Wang, Yang, Liu, Li, Yang, et al., 2021). Photoluminescence (PL) studies reveal high radiative recombination efficiencies, indicating low non-radiative recombination losses. These properties make CsPbI₂Br a strong candidate for efficient light-harvesting and light-emitting applications (Haider et al., 2024).

One of the main challenges with halide perovskites is their stability under operational conditions. CsPbI₂Br shows improved thermal and moisture stability compared to organic-inorganic hybrid perovskites like MAPbI₃, due to the absence of volatile organic components (Ahmed et al., 2022). However, it still undergoes degradation under prolonged exposure to light and humidity. Encapsulation techniques and the use of protective barrier layers have been explored to enhance the long-term stability of CsPbI₂Br-based devices. Recent studies also focus on compositional engineering to improve intrinsic stability, such as using mixed halides to reduce phase segregation (Ullah, Wang, Yang, Liu, Li, Yang, et al., 2021).

When compared to other halide perovskites, CsPbI₂Br offers a unique balance of electrical and optical properties. For instance, it has a higher thermal stability than MAPbI₃ and better moisture resistance than FAPbI₃ (Miyasaka & Jena, 2021). However, its higher bandgap limits its application in low-bandgap requirements but makes it ideal for tandem solar cells and visible light emitters (Chen, 2022). Performance metrics such as power conversion efficiency (PCE) in solar cells show CsPbI₂Br achieving over 15% in single-junction configurations, which is competitive but still lower than the highest efficiencies reported for MAPbI₃. Continued research is focusing on overcoming these performance gaps through material and interface engineering (Yang et al., 2023).

Despite the promising properties of CsPbI₂Br, challenges remain in achieving high performance and stability in devices. The main limitations include managing defect densities, improving long-term stability, and scaling up production while maintaining quality (Ullah, Wang, Yang, Liu, Li, Yang, et al., 2021). Future research directions include the development of novel synthesis methods to produce defect-free films, advanced encapsulation techniques to enhance stability, and the exploration of new doping and alloying strategies to further tune the electrical and optical properties (Miyasaka et al., 2020).

This review focuses on the electrical and optical properties of CsPbI₂Br and its variants, comparing them with other halide perovskites to highlight their potential and challenges.

2- Method

In this review article, a comprehensive literature search was conducted to gather relevant studies on the electrical and optical properties of CsPbI₂Br and its variants. The methodology for the selection and analysis of the literature is detailed as follows:

The literature search was performed using multiple reputable databases to ensure a wide coverage of published research. The primary databases used were “Scopus”, “Web of Science” and, “Google Scholar”. These databases were chosen for their extensive indexing of scientific journals, conference proceedings, and technical reports, providing a robust foundation for a thorough review.

A systematic search was developed to identify relevant articles. The following keywords and phrases were used in various combinations to ensure comprehensive coverage "CsPbI₂Br", "cesium lead halide perovskites", "electrical properties of CsPbI₂Br", "optical properties of CsPbI₂Br", "CsPbI₂Br synthesis methods", "stability of CsPbI₂Br", "perovskite solar cells" and, "optoelectronic applications of CsPbI₂Br". Boolean operators (AND, OR) were used to refine the search results, and filters were applied to include only peer-reviewed articles, review papers, and significant conference proceedings published in English.

To ensure the relevance and quality of the selected articles, the following inclusion and exclusion criteria were applied:

- Inclusion Criteria:
 - Articles focused on CsPbI₂Br or its variants.
 - Studies examining electrical and optical properties.
 - Papers discussing synthesis methods, stability, and optoelectronic applications.
 - Publications from reputable journals and conferences.
- Exclusion Criteria:
 - Articles not available in full text.
 - Studies not related to the main topic, such as those focused on other types of perovskites without mention of CsPbI₂Br.
 - Non-peer-reviewed sources, such as opinion pieces or editorial comments.

The extracted data were analyzed to identify trends, common findings, and significant variations across different studies. Comparative analyses were conducted to highlight the differences and similarities in the electrical and optical properties of CsPbI₂Br and its variants. Special attention was given to studies that provided quantitative data, such as charge carrier mobility, absorption coefficients, and device performance metrics.

The results from the data analysis were synthesized to provide a comprehensive overview of the current state of research on CsPbI₂Br. This methodological approach ensured a rigorous and systematic review of the literature, providing a detailed and balanced perspective on the electrical and optical properties of CsPbI₂Br and its variants.

3- Results and Discussion

3.1- Structural Characteristics of CsPbI₂Br

3.1.1- Crystal Structure

CsPbI₂Br, a mixed halide perovskite, adopts a perovskite crystal structure similar to other halide perovskites, which can be described by the general formula ABX₃. In this structure:

- A-site: Cesium (Cs⁺)
- B-site: Lead (Pb²⁺)

- X-site: A mixture of halides, iodide (I-) and bromide (Br-)

The crystal structure of CsPbI₂Br is generally tetragonal at room temperature, which transitions to a cubic phase at higher temperatures (Zeng et al., 2019). The tetragonal phase is characterized by a slight distortion in the lattice compared to the ideal cubic structure, which can affect the material's electronic properties.

3.1.2- Lattice Parameters

The lattice parameters of CsPbI₂Br have been studied and reported in several publications. For the tetragonal phase, typical lattice parameters are:

- $a \approx 6.15 \text{ \AA}$
- $c \approx 11.65 \text{ \AA}$

These parameters are indicative of a slight elongation along the c-axis compared to the a-axis. The precise values of these parameters can vary slightly depending on the synthesis methods and specific conditions used (Chen et al., 2019).

3.1.3- Phase Stability

Phase stability is a crucial aspect of perovskite materials, as different phases can exhibit significantly different properties. CsPbI₂Br shows enhanced phase stability compared to its purely iodide or bromide counterparts. The presence of both iodide and bromide ions helps to stabilize the structure, reducing the likelihood of phase transitions that could negatively affect the material's performance in devices (Chen et al., 2019).

At room temperature, CsPbI₂Br typically exists in the tetragonal phase. This phase is relatively stable and does not transition easily to other phases under ambient conditions. Upon heating, CsPbI₂Br transitions to a cubic phase. This phase transition generally occurs around 300°C, which indicates good thermal stability for applications that might involve elevated temperatures (Haider et al., 2024). While CsPbI₂Br is more stable than many other perovskites, it is still sensitive to moisture and can degrade under high humidity conditions. The degradation often leads to the formation of lead iodide (PbI₂) and cesium bromide (CsBr), which deteriorates the material's optoelectronic properties. Efforts to mitigate this issue include surface passivation and encapsulation strategies to protect the material from environmental exposure (Zeng et al., 2019).

The phase stability can also be influenced by compositional tuning. For instance, partial substitution of bromide with chloride can further stabilize the crystal structure and enhance moisture resistance (Atourki et al., 2021). This compositional flexibility allows researchers to optimize the material for specific applications and environmental conditions.

3.1.4- Comparison with Other Halide Perovskites

Compared to other halide perovskites such as MAPbI₃ (methylammonium lead iodide) and FAPbI₃ (formamidinium lead iodide), CsPbI₂Br offers superior thermal stability due to the inorganic nature of cesium, which does not decompose at high temperatures (Zeng et al., 2019);(Ghaithan et al., 2021). This makes CsPbI₂Br particularly attractive for applications where thermal stability is critical, such as in solar cells and LEDs that operate under intense sunlight or high current densities. In summary, the structural characteristics of CsPbI₂Br, including its lattice parameters and phase stability, make it a promising material for various optoelectronic applications. Its enhanced thermal stability and the potential for compositional tuning provide avenues for further optimization and application in stable, high-performance devices.

3.2- Variants of CsPbI₂Br

The performance and stability of CsPbI₂Br perovskites can be significantly enhanced through various modifications, including alloying with other elements, doping, and incorporating different halides. These modifications can tailor the material's properties for specific applications and improve its overall performance.

3.2.1- Alloying with Other Elements

Alloying CsPbI₂Br with different elements is a common strategy to adjust its electronic and optical properties. Alloying involves substituting a portion of the A-site, B-site, or X-site ions with different ions.

A-Site Alloying:

- FA (Formamidinium) and MA (Methylammonium): Replacing some cesium ions (Cs⁺) with organic cations like formamidinium (FA⁺) or methylammonium (MA⁺) can improve the film quality and optoelectronic properties. For example, FA_{0.83}Cs_{0.17}PbI₂Br has been shown to exhibit enhanced stability and photovoltaic performance due to the improved tolerance to defects and better film formation (Zhao et al., 2021).

B-Site Alloying:

- Tin (Sn): Partial substitution of lead (Pb²⁺) with tin (Sn²⁺) can lower the bandgap and enhance the material's environmental friendliness. CsPb_{1-x}Sn_xI₂Br alloys have shown promising results in achieving lower bandgaps and improved charge transport properties, although the stability of tin-containing perovskites remains a challenge (Guo et al., 2019).

3.2.2- Doping

Doping involves introducing small amounts of foreign atoms into the perovskite lattice to improve its properties.

Halide Doping:

- Chlorine (Cl⁻) and Fluorine (F⁻): Doping CsPbI₂Br with small amounts of chlorine or fluorine can enhance the material's stability and optical properties. Chlorine doping (CsPbI₂Br:Cl) has been found to passivate defects and improve moisture resistance, resulting in better device performance and longevity (Akman et al., 2023).

Metal Cation Doping:

- Alkali Metals: Doping with alkali metals like sodium (Na⁺) or potassium (K⁺) can enhance the material's charge transport properties and stability. For instance, Na-doped CsPbI₂Br has shown improved thermal stability and reduced ion migration, which are crucial for stable device operation (Mali et al., 2021).

3.2.3- Incorporating Different Halides

Incorporating different halides into the CsPbI₂Br lattice allows for fine-tuning of the bandgap and stabilization of the crystal structure.

Mixed Halide Perovskites:

- CsPbI₂-xBr_x: By varying the ratio of iodide (I⁻) to bromide (Br⁻), researchers can precisely control the bandgap and phase stability of the perovskite. Increasing the bromide content generally increases the bandgap, making the material more suitable for applications requiring higher energy absorption or emission.

Conversely, increasing iodide content lowers the bandgap, enhancing light absorption in the visible spectrum (Igual-Munoz et al., 2020).

- **CsPbI₂-xCl_x:** Incorporating chloride ions (Cl⁻) into the lattice can enhance stability and improve crystallinity. Chloride doping has been shown to reduce defect densities and enhance the material's resistance to environmental degradation, making it more suitable for long-term applications (Qiu et al., 2021).

Quaternary Halide Systems:

- **CsPb(BrxI_{1-x})₃:** Complex mixed halide systems where the halide composition is varied continuously from pure iodide to pure bromide have been explored to achieve a balance between high stability and optimal bandgap. Such quaternary systems can provide intermediate properties that are not achievable with simple binary or ternary compositions (Chen et al., 2021).

Mixed A-site Cations:

- **FA-Cs Mixed Cation:** A study by (Akman et al., 2023) demonstrated that adding formamidinium (FA) to CsPbI₂Br (resulting in FA_{0.83}Cs_{0.17}PbI₂Br) improved the overall stability and efficiency of perovskite solar cells.

B-site Alloying with Sn:

- **Tin Alloying:** Research by (G. Wang et al., 2020) investigated the effects of partially replacing lead with tin in CsPbI₂Br, showing that Sn alloying can tune the bandgap and improve charge carrier dynamics, although the material's stability was a concern.

Halide Doping with Cl:

- **Chlorine Doping:** (Lim et al., 2023) reported that doping CsPbI₂Br with chlorine enhanced its photostability and reduced trap states, resulting in better performance in optoelectronic devices.

Mixed Halide Systems:

- **CsPbI₂-xBr_x:** The work by (Yang et al., 2023) on mixed halide perovskites demonstrated how varying the bromide to iodide ratio can optimize the optical properties and stability of the material for specific applications.

Table 1: Summary of the various modifications applied to CsPbI₂Br

Modification Type	Variant	Description	Performance/Benefit	References
Alloying with Other Elements	A-Site Alloying	Replacing Cs ⁺ with organic cations (FA ⁺ or MA ⁺).	Improved film quality, enhanced stability, and photovoltaic performance.	(Zhao et al., 2021)
	B-Site Alloying	Partial substitution of Pb ²⁺ with Sn ²⁺ .	Lower bandgap, improved charge transport properties, environmental friendliness.	(Guo et al., 2019)

Doping	Halide Doping	Introducing small amounts of Cl ⁻ or F ⁻ .	Enhanced stability, passivated defects, improved moisture resistance.	(Akman et al., 2023)
	Metal Cation Doping	Doping with alkali metals like Na ⁺ or K ⁺ .	Enhanced charge transport properties, improved thermal stability, reduced ion migration.	(Mali et al., 2021)
Incorporating Different Halides	Mixed Halide Perovskites	Varying the ratio of iodide to bromide (CsPbI ₂ -xBr _x).	Precise control of bandgap, enhanced phase stability, tailored optical properties.	(Igual-Munoz et al., 2020)
	Chloride Incorporation	Introducing Cl ⁻ ions into the lattice (CsPbI ₂ -xCl _x).	Enhanced stability, improved crystallinity, reduced defect densities, resistance to environmental degradation.	(Qiu et al., 2021)
	Quaternary Halide Systems	Complex systems with varied halide composition (CsPb(BrxI _{1-x}) ₃).	Balance between high stability and optimal bandgap, intermediate properties.	(Chen et al., 2021)
Mixed A-site Cations	FA-Cs Mixed Cation	Adding FA to CsPbI ₂ Br (FA _{0.83} Cs _{0.17} PbI ₂ Br).	Improved overall stability and efficiency of perovskite solar cells.	(Akman et al., 2023)
B-site Alloying with Sn	Tin Alloying	Partially replacing Pb with Sn in CsPbI ₂ Br.	Tuned bandgap, improved charge carrier dynamics, though with stability concerns.	(G. Wang et al., 2020)
Halide Doping with Cl	Chlorine Doping	Doping CsPbI ₂ Br with chlorine.	Enhanced photostability, reduced trap states, better optoelectronic device performance.	(Lim et al., 2023)
Mixed Halide Systems	CsPbI ₂ -xBr _x	Varying bromide to iodide ratio.	Optimized optical properties and stability for specific applications.	(Yang et al., 2023)

3.3- Synthesis Methods for CsPbI₂Br and its Variants

3.3.1- Chemical Vapor Deposition (CVD)

Chemical Vapor Deposition (CVD) is a widely used technique for the deposition of thin films with high uniformity and control over thickness. In CVD, gaseous precursors react on a heated substrate to form a solid film.

Application in CsPbI₂Br Synthesis:

- **High-Quality Films:** CVD is particularly advantageous for producing high-quality perovskite films with controlled composition and thickness. This method can ensure excellent uniformity and large-area coverage, which are essential for device fabrication (Kim, 2024).
- **Phase Control:** CVD allows precise control over the reaction environment, which can be used to stabilize specific phases of CsPbI₂Br and its variants, enhancing their performance in optoelectronic applications (Bonomi & Malavasi, 2020).

Challenges:

- **Complexity and Cost:** The setup for CVD is relatively complex and expensive compared to solution-processed methods. Additionally, controlling the stoichiometry of mixed-halide perovskites can be challenging (Ullah, Wang, Yang, Liu, Li, Rehman, et al., 2021).

3.3.2- Solution-Processed Methods

Solution-processed methods are popular for their simplicity, cost-effectiveness, and scalability. These methods include techniques like spin coating and solvent engineering.

Spin Coating:

- **Process:** In spin coating, a solution of perovskite precursors is deposited on a substrate, which is then spun at high speeds to form a uniform thin film.
- **Advantages:** This method is straightforward, fast, and allows for easy tuning of film thickness by adjusting the spinning speed and solution concentration (Gao et al., 2018).
- **Application:** Spin coating has been extensively used to fabricate CsPbI₂Br films with high uniformity and good crystallinity. For instance, studies have shown that spin coating can produce high-quality films suitable for efficient solar cells and light-emitting devices (Zhang et al., 2018).

Solvent Engineering:

- **Process:** Solvent engineering involves optimizing the solvent system used to dissolve the perovskite precursors to control the crystallization process.
- **Advantages:** By carefully selecting solvents and additives, researchers can enhance film morphology, improve crystal quality, and passivate defects (Wang et al., 2022).
- **Application:** Techniques such as antisolvent dripping during spin coating have been employed to enhance the film quality of CsPbI₂Br. This method helps in achieving smoother films with fewer pinholes and better optoelectronic properties (Zhang et al., 2018).

Challenges:

- **Reproducibility:** Solution-processed methods can sometimes suffer from reproducibility issues due to the sensitivity of the process parameters (Bai et al., 2018).

3.3.3- Other Techniques

Other advanced techniques such as vapor-assisted solution processes and hot injection methods offer additional avenues for synthesizing high-quality perovskite films.

Vapor-Assisted Solution Process:

Link: <https://scieropub.com/pv/DSI141258475746>

- **Process:** This method involves first depositing a precursor film from solution, followed by exposure to vapor of another reactant to complete the formation of the perovskite.
- **Advantages:** The vapor-assisted approach can improve the crystallinity and purity of the perovskite film. It also allows better control over the stoichiometry and composition (Liu et al., 2020).
- **Application:** For CsPbI₂Br, vapor-assisted processes have been used to achieve better control over halide distribution, resulting in films with improved optical properties and stability (Ullah, Wang, Yang, Liu, Li, Yang, et al., 2021).

Hot Injection Method:

- **Process:** In the hot injection method, precursors are rapidly injected into a hot solvent, leading to the rapid nucleation and growth of perovskite nanocrystals.
- **Advantages:** This method is known for producing high-quality nanocrystals with controlled size and excellent uniformity. It allows precise control over the reaction kinetics, leading to highly crystalline products (Ghorai et al., 2022).
- **Application:** CsPbI₂Br nanocrystals synthesized via hot injection have shown enhanced photoluminescence and stability, making them suitable for applications in light-emitting devices and photodetectors (Huang et al., 2023).

Challenges:

- **Scalability:** While these techniques can produce high-quality materials, scaling them up for large-area device fabrication can be challenging (Huang et al., 2023).

3.4- Comparison of Synthesis Methods for Producing High-Quality CsPbI₂Br Films

3.4.1- Chemical Vapor Deposition (CVD)

Advantages:

1. **High Film Quality:** CVD produces films with excellent uniformity, high crystallinity, and low defect densities, which are crucial for high-performance optoelectronic devices (Kim, 2024).
2. **Thickness Control:** The method allows precise control over the film thickness, which is beneficial for optimizing device structures (Calisi et al., 2022).
3. **Scalability:** CVD is scalable for large-area deposition, making it suitable for industrial applications (Ma et al., 2023).

Disadvantages:

1. **Complexity and Cost:** The setup for CVD is complex and costly, requiring high temperatures and vacuum conditions, which may limit its widespread use in research and small-scale applications (Bonomi & Malavasi, 2020).
2. **Stoichiometry Control:** Maintaining precise stoichiometry of mixed-halide perovskites like CsPbI₂Br can be challenging in a CVD process, potentially leading to compositional variations (Zhang et al., 2023).

3.4.2- Solution-Processed Methods

Spin Coating:

Advantages:

1. **Simplicity and Cost-Effectiveness:** Spin coating is a straightforward, low-cost technique that does not require expensive equipment, making it accessible for many research laboratories (Yin et al., 2018).
2. **Rapid Deposition:** The process is quick and can produce uniform films with controlled thickness by adjusting spinning parameters (Fan et al., 2019).

Disadvantages:

1. **Reproducibility Issues:** Achieving consistent film quality can be challenging due to sensitivity to environmental conditions such as humidity and temperature (Lv et al., 2020).
2. **Scalability:** While suitable for small-scale applications, spin coating may face challenges when scaling up for large-area devices (Fan et al., 2019).

Solvent Engineering:

Advantages:

1. **Enhanced Film Quality:** Optimizing solvent systems and using antisolvent techniques can significantly improve film morphology, reduce defects, and enhance crystallinity (Zhang et al., 2018).
2. **Versatility:** Solvent engineering allows for fine-tuning of the crystallization process, which can be tailored to specific material compositions and desired properties (Rezaee et al., 2021).

Disadvantages:

1. **Complex Process:** Requires careful selection and control of solvents and additives, which can be time-consuming and requires extensive experimentation (Wang et al., 2022).
2. **Environmental Sensitivity:** Similar to spin coating, solvent-engineered films can be sensitive to ambient conditions, impacting reproducibility (Park et al., 2021).

3.4.3- Other Techniques

Vapor-Assisted Solution Process:

Advantages:

1. **Improved Crystallinity:** Combining solution processing with vapor treatment enhances the crystal quality and purity of the films (Liu et al., 2020).
2. **Composition Control:** This method allows better control over the stoichiometry and composition, which is crucial for achieving desired material properties (Ullah, Wang, Yang, Liu, Li, Rehman, et al., 2021).

Disadvantages:

1. **Process Complexity:** This method is more complex than simple solution processing, requiring additional steps and equipment for vapor treatment (Fan et al., 2019).

2. Scalability: Although it improves film quality, scaling up vapor-assisted processes for large-area deposition can be challenging (Liu et al., 2020).

Hot Injection Method:

Advantages:

1. High-Quality Nanocrystals: Produces highly crystalline nanocrystals with controlled size, which are beneficial for optoelectronic applications (Xu et al., 2022).
2. Rapid Synthesis: The hot injection method allows for rapid nucleation and growth of nanocrystals, leading to high reproducibility.

Disadvantages:

1. Limited Film Application: Primarily used for synthesizing nanocrystals rather than thin films, which may limit its direct application in film-based devices (Xu et al., 2022).
2. Scalability Issues: Scaling up the hot injection process while maintaining uniform quality and properties can be difficult (Song et al., 2022).

Each synthesis method for CsPbI₂Br films has its unique advantages and disadvantages, making them suitable for different applications and contexts.

- CVD is ideal for high-quality, uniform films with excellent thickness control, suitable for industrial-scale production, but it is complex and expensive.
- Spin Coating and Solvent Engineering offer simplicity, cost-effectiveness, and rapid processing, making them popular in research, though they face challenges in reproducibility and scalability.
- Vapor-Assisted Solution Processes provide improved film quality and composition control, at the cost of added complexity and scalability issues.
- Hot Injection Methods are excellent for producing high-quality nanocrystals but are less applicable for thin-film applications and difficult to scale.

Selecting the appropriate method depends on the specific requirements of the application, including the desired film quality, cost constraints, and scalability needs.

Table 2: Synthesis Methods for CsPbI₂Br and Their Comparison

Method	Advantages	Disadvantages	References
CVD	High-quality films, excellent uniformity, phase control, scalable	Complex, costly setup, challenging stoichiometry control	(Kim, 2024); (Bonomi & Malavasi, 2020); (Ullah et al., 2021); (Calisi et al., 2022); (Ma et al., 2023); (Zhang et al., 2023)
Spin Coating	Simple, fast, low-cost, easy thickness tuning	Reproducibility issues, scalability challenges	(Gao et al., 2018); (Zhang et al., 2018); (Bai et al., 2018); (Yin et al.,

			2018) (Fan et al., 2019); (Lv et al., 2020)
Solvent Engineering	Enhanced film and crystal quality, versatile	Complex, time-consuming, sensitive to ambient conditions	(Wang et al., 2022); (Zhang et al., 2018); (Park et al., 2021); (Rezaee et al., 2021)
Vapor-Assisted	Improved crystallinity and purity, better stoichiometry control	More complex process, scalability issues	(Liu et al., 2020); (Ullah et al., 2021); (Fan et al., 2019)
Hot Injection	High-quality nanocrystals, rapid synthesis	Limited for thin films, difficult scalability	(Ghorai et al., 2022); (Huang et al., 2023); (Xu et al., 2022); (Song et al., 2022)

3.5- Electrical Properties of CsPbI₂Br and its Variants

The electrical properties of CsPbI₂Br and its variants play a crucial role in determining their performance in optoelectronic devices such as solar cells, photodetectors, and light-emitting diodes. Understanding conductivity, charge carrier mobility, and defect states is essential for optimizing device performance and stability.

3.5.1- Conductivity

Intrinsic Conductivity:

- CsPbI₂Br exhibits intrinsic conductivity arising from its intrinsic charge carriers, which are generated due to thermal excitation across the bandgap. The conductivity of intrinsic CsPbI₂Br is relatively low under normal conditions, limiting its application in electronic devices (Chen et al., 2019).

Extrinsic Conductivity and Doping Effects:

- Extrinsic conductivity in CsPbI₂Br can be enhanced through doping with foreign atoms. Doping introduces additional charge carriers into the material, thereby increasing its conductivity. Common dopants include alkali metals (e.g., Na, K), halogens (e.g., Cl, F), and transition metals (e.g., Sn) (Zhang et al., 2022).
- For example, Na doping has been shown to improve the electrical conductivity and stability of CsPbI₂Br films by reducing defect densities and enhancing carrier transport (G. Wang et al., 2020).
- Similarly, chlorine doping can passivate defects and improve the material's conductivity and stability, making it more suitable for practical device applications (G. Wang et al., 2020).

3.5.2- Charge Carrier Mobility

Measurement Methods:

- Charge carrier mobility in CsPbI₂Br and its variants is typically measured using various techniques such as time-of-flight (TOF) transient photocurrent, space-charge-limited current (SCLC), and field-effect transistor (FET) measurements (Zeng et al., 2019).

- TOF transient photocurrent measurements provide information about the carrier transit time and mobility, while SCLC measurements can determine the charge carrier mobility in thin-film devices under an applied electric field.
- FET measurements allow for direct measurement of charge carrier mobility in field-effect devices, providing valuable insights into charge transport mechanisms.

Typical Values:

- The charge carrier mobility in CsPbI₂Br and its variants can vary depending on factors such as film quality, composition, and doping level.
- Reported values for charge carrier mobility in CsPbI₂Br range from around 1 to 100 cm²/Vs, with higher mobility typically observed in films with lower defect densities and improved crystallinity (Chen et al., 2019).
- Doping with suitable dopants can also lead to enhanced charge carrier mobility by reducing trap states and improving charge transport properties.

3.5.3- Defect States

Types of Defects:

- Common defects found in CsPbI₂Br include vacancies, interstitials, and antisite defects, which can introduce localized states within the bandgap and act as recombination centers for charge carriers (Chen et al., 2019).
- Vacancies, such as iodine vacancies (V_I) and lead vacancies (V_{Pb}), are prevalent defects in halide perovskites and can significantly impact their electronic properties.
- Interstitial defects, where foreign atoms occupy interstitial lattice sites, can also affect charge transport and recombination processes.
- Antisite defects occur when atoms occupy sites intended for other species, disrupting the crystal structure and introducing additional trap states.

Effects on Electrical Properties:

- Defect states in CsPbI₂Br can lead to non-radiative recombination of charge carriers, reducing device efficiency and stability.
- Trap-assisted recombination processes can limit the charge carrier lifetime and increase the dark current in devices, leading to performance degradation over time (Dong et al., 2024).

Strategies to Mitigate Defects:

- Passivation of defects through chemical treatments or interface engineering can mitigate their detrimental effects on device performance.
- For example, surface passivation using organic or inorganic passivating agents can reduce trap densities and suppress non-radiative recombination, leading to improved device efficiency and stability (Jin et al., 2021).
- Additionally, careful control of the synthesis conditions, such as precursor stoichiometry, processing temperature, and annealing protocols, can minimize the formation of defects and improve the material's electrical properties (Chen et al., 2019).

3.6- Optical Properties of CsPbI₂Br and its Variants

3.6.1- Absorption and Emission Spectra

Absorption Coefficient:

- The absorption coefficient of CsPbI₂Br is influenced by its bandgap energy and the presence of defects and impurities. High absorption coefficients are desirable for efficient light harvesting in solar cells and photodetectors (Liang et al., 2020).
- CsPbI₂Br typically exhibits strong absorption in the visible and near-infrared regions, making it suitable for applications requiring broad spectral response (Zhu et al., 2019).

Photoluminescence and Emission Spectra:

- Photoluminescence (PL) spectroscopy provides insights into the radiative recombination processes and the bandgap energy of CsPbI₂Br.
- CsPbI₂Br exhibits intense photoluminescence emission in the green to red region, with peak emission wavelengths ranging from approximately 550 nm to 700 nm (Liang et al., 2020).
- Emission spectra analysis can reveal information about defect states, bandgap energies, and material quality, which are crucial for device performance optimization.

3.6.2- Bandgap Engineering

Methods for Tuning Bandgap:

- Bandgap engineering in CsPbI₂Br can be achieved through compositional variations, structural modifications, and external stimuli.
- Alloying CsPbI₂Br with other halides such as bromine or chlorine can tune its bandgap, allowing for optimization of the optical and electronic properties (Scognamillo, 2019).
- Structural modifications, such as controlling crystal orientation or grain size, can also influence the bandgap and optical absorption properties of CsPbI₂Br (Lin et al., 2022).
- External stimuli such as temperature, pressure, or electric field can induce changes in the bandgap, offering additional avenues for bandgap engineering (Lin et al., 2022).

3.6.3- Optoelectronic Applications

Performance Metrics in Devices:

- In solar cells, CsPbI₂Br-based devices have demonstrated high power conversion efficiencies (PCEs) exceeding 20%, making them promising candidates for next-generation photovoltaics (Alsaad et al., 2024).
- In LEDs, CsPbI₂Br emitters exhibit narrow emission linewidths, high color purity, and tunable emission wavelengths, enabling the development of efficient and color-tunable light sources (Lozano, 2018).
- In photodetectors, CsPbI₂Br-based devices have shown high responsivity, fast response times, and low noise levels, making them suitable for various sensing applications (Xu et al., 2019).

Challenges:

- Despite the promising optical properties and performance metrics of CsPbI₂Br-based devices, challenges such as stability, scalability, and reproducibility need to be addressed for practical implementation.
- Strategies for enhancing device stability, improving material synthesis reproducibility, and scaling up device fabrication processes are essential for realizing the full potential of CsPbI₂Br in optoelectronic applications.

3.7- Stability and Degradation of CsPbI₂Br and its Variants

Ensuring the stability of CsPbI₂Br and its variants is crucial for the long-term performance and reliability of optoelectronic devices. Understanding thermal stability, moisture sensitivity, and photostability, along with strategies to mitigate degradation, is essential for advancing the practical applications of these materials.

3.7.1- Thermal Stability

Thermal Behavior and Decomposition Temperatures:

- CsPbI₂Br exhibits unique thermal behavior, with decomposition occurring at relatively low temperatures compared to other perovskite materials.
- The decomposition temperature of CsPbI₂Br typically ranges from 200°C to 300°C, depending on factors such as film morphology, composition, and processing conditions (Mariotti et al., 2018).
- Thermal decomposition pathways involve the release of volatile iodine species, formation of lead iodide (PbI₂) phases, and structural reorganization, leading to the degradation of material properties (P. Wang et al., 2020).

3.7.2- Moisture Sensitivity

Effects of Humidity:

- CsPbI₂Br is highly sensitive to moisture, which can induce rapid degradation through processes such as halide ion exchange, phase transitions, and formation of hydrated phases.
- Exposure to moisture leads to the formation of PbI₂ and CsI phases, resulting in a loss of crystallinity, reduced charge carrier mobility, and degradation of device performance (Fan et al., 2019).
- Moisture-induced degradation mechanisms include the formation of hydrolyzed Pb-O bonds, migration of halide ions, and corrosion of metal electrodes (Fan et al., 2019).

Methods to Improve Moisture Resistance:

- Several strategies have been proposed to enhance the moisture resistance of CsPbI₂Br-based materials, including interface engineering, encapsulation, and chemical passivation.
- Interface engineering techniques involve modifying the surface chemistry of CsPbI₂Br films to reduce moisture ingress and improve adhesion to encapsulation layers (Yang et al., 2020).
- Encapsulation with moisture-impermeable materials such as glass, polymers, or metal oxides can provide an effective barrier against moisture ingress, preserving the structural integrity and performance of CsPbI₂Br-based devices (Lv et al., 2019).

- Chemical passivation of CsPbI₂Br surfaces with hydrophobic coatings or self-assembled monolayers can minimize moisture-induced degradation by reducing water adsorption and surface reactions (Cao et al., 2024).

3.7.3- Photostability

Degradation Under Light Exposure:

- CsPbI₂Br is susceptible to photodegradation when exposed to light, especially in the presence of oxygen and moisture.
- Photodegradation mechanisms involve the generation of reactive oxygen species (ROS), photoinduced phase transitions, and ion migration, leading to the formation of non-radiative recombination centers and structural defects (Gutsev et al., 2023).
- Common manifestations of photodegradation include reduced photoluminescence intensity, decreased charge carrier lifetime, and diminished device performance (P. Wang et al., 2020).

Protective Strategies:

- Protective strategies to enhance the photostability of CsPbI₂Br include the use of encapsulation layers, antireflection coatings, and light filtering techniques.
- Encapsulation with UV-blocking materials can shield CsPbI₂Br films from harmful UV radiation, reducing photodegradation rates and prolonging device lifetime (Wei et al., 2021).
- Antireflection coatings can minimize light-induced heating effects and enhance photon absorption, improving the overall photostability and performance of CsPbI₂Br-based devices (Scognamillo, 2019).
- Light filtering techniques such as spectral filtering or light management schemes can selectively attenuate harmful wavelengths while maintaining high photon flux in the desired spectral range, mitigating photodegradation effects (Hu et al., 2024).

3.8- Comparison of CsPbI₂Br with Other Halide Perovskites

CsPbI₂Br, along with other halide perovskites such as MAPbI₃, FAPbI₃, and CsPbBr₃, represents a diverse class of materials with unique properties. Understanding how CsPbI₂Br compares to these popular perovskites in terms of both electrical and optical properties is essential for evaluating its potential in various optoelectronic applications.

3.8.1- Electrical Properties

Carrier Mobility:

- CsPbI₂Br typically exhibits lower charge carrier mobility compared to MAPbI₃ and FAPbI₃ due to its narrower bandgap and heavier constituent elements (Hamieddine et al., 2021).
- MAPbI₃ and FAPbI₃ have been reported to have charge carrier mobilities ranging from tens to hundreds of cm²/Vs, while CsPbI₂Br typically exhibits mobilities in the range of a few to tens of cm²/Vs (Zeng et al., 2019).

Stability:

- CsPbI₂Br is known for its relatively poor stability compared to MAPbI₃ and FAPbI₃, especially under ambient conditions and light exposure.

- MAPbI₃ and FAPbI₃ have shown better stability in terms of moisture resistance, thermal stability, and photostability, making them more suitable for practical device applications (Chen et al., 2019);(Zhou & Zhao, 2019).

3.8.2- Optical Properties

Absorption Coefficient:

- CsPbI₂Br typically exhibits a broader absorption spectrum compared to MAPbI₃ and FAPbI₃, extending into the near-infrared region due to its narrower bandgap.
- MAPbI₃ and FAPbI₃, on the other hand, have higher absorption coefficients in the visible spectrum, making them more suitable for solar cell applications requiring efficient light harvesting (Chen et al., 2019).

Emission Properties:

- CsPbI₂Br exhibits unique emission properties, with emission peaks in the green to red region, depending on composition and processing conditions (Zeng et al., 2019).
- MAPbI₃ and FAPbI₃ also exhibit strong photoluminescence emission, typically in the visible region, with emission peaks ranging from blue to red (Yin et al., 2018).

3.8.3- Comparison

- CsPbI₂Br: Narrow bandgap, lower charge carrier mobility, and relatively poor stability compared to MAPbI₃ and FAPbI₃. Broad absorption spectrum extending into the near-infrared region.
- MAPbI₃ and FAPbI₃: Wider bandgap, higher charge carrier mobility, and better stability compared to CsPbI₂Br. Higher absorption coefficients in the visible spectrum, making them more suitable for solar cell applications.

3.9- Comparative Analysis of CsPbI₂Br Performance Metrics

Comparing the performance metrics of CsPbI₂Br-based devices with those of other perovskite materials is crucial for assessing its potential in optoelectronic applications. This comparative analysis focuses on benchmarking device performance, particularly in terms of power conversion efficiency (PCE) in solar cells, against other popular perovskite materials.

3.9.1- Benchmarking PCE in Solar Cells

CsPbI₂Br Performance:

- Recent studies have demonstrated promising PCEs for CsPbI₂Br-based solar cells, with reported efficiencies exceeding 18% (Parida et al., 2020).
- CsPbI₂Br offers unique advantages such as a narrower bandgap, suitable for tandem cell configurations, and broader absorption spectra extending into the near-infrared region (Ullah, Wang, Yang, Liu, Li, Yang, et al., 2021).

Comparison with MAPbI₃ and FAPbI₃:

- MAPbI₃ and FAPbI₃ have been extensively studied for their high PCEs in perovskite solar cells, with record efficiencies surpassing 25% (Ren et al., 2022).

- These materials have excellent charge carrier mobility, stability, and optoelectronic properties, making them benchmark materials for comparison.

Key Findings:

- While CsPbI₂Br exhibits lower PCEs compared to MAPbI₃ and FAPbI₃, its unique properties make it a promising candidate for tandem cell configurations and spectral complementarity.
- CsPbI₂Br-based solar cells offer advantages in terms of broader spectral absorption and potential compatibility with low-cost, solution-processed fabrication techniques (Tang, 2019).

3-10. Challenges in Utilizing CsPbI₂Br in Practical Applications

While CsPbI₂Br holds great promise for various optoelectronic applications, several challenges must be addressed to realize its full potential. Understanding these current limitations is essential for overcoming hurdles and advancing the practical utilization of CsPbI₂Br in diverse applications.

3.10.1- Stability Issues

Hygroscopic Nature:

- One significant challenge is the hygroscopic nature of CsPbI₂Br, which makes it susceptible to moisture-induced degradation.
- Moisture can lead to phase transitions, structural degradation, and the formation of undesirable phases such as PbI₂ and CsI, compromising device performance and stability (Lim et al., 2023).

Thermal Stability:

- CsPbI₂Br exhibits relatively poor thermal stability compared to other perovskite materials, with decomposition occurring at relatively low temperatures.
- Thermal degradation pathways involve the release of volatile iodine species, phase transitions, and structural reorganization, limiting device lifetimes and reliability (Ullah, Wang, Yang, Liu, Li, Yang, et al., 2021).

3.10.2- Defect Engineering

High Density of Defect States:

- CsPbI₂Br films often suffer from a high density of defect states, including vacancies, interstitials, and antisite defects, which can act as recombination centers for charge carriers.
- These defects reduce charge carrier lifetimes, increase non-radiative recombination, and degrade device performance (Chen et al., 2019).

3.10.3- Material Processing

Film Formation and Morphology:

- Achieving uniform, pinhole-free CsPbI₂Br films with optimal morphology is challenging, particularly for large-area deposition techniques.
- Non-uniform film coverage, surface roughness, and grain boundaries can lead to localized degradation, poor charge transport, and reduced device efficiency (Ullah, Wang, Yang, Liu, Li, Yang, et al., 2021).

3.10.4- Encapsulation and Device Integration

Encapsulation Requirements:

- CsPbI₂Br-based devices require effective encapsulation to protect against moisture and oxygen ingress, but conventional encapsulation techniques can introduce additional processing complexity and cost.
- Developing scalable encapsulation methods compatible with CsPbI₂Br processing conditions is essential for practical device integration (Lim et al., 2023).

3.11- Recent Advancements in CsPbI₂Br Research Trends

Recent research efforts have focused on advancing the understanding of CsPbI₂Br properties and exploring its potential in various optoelectronic applications. Highlighting these recent advancements sheds light on emerging trends and directions in CsPbI₂Br research.

3.11.1- Improved Stability

Stabilization Strategies:

- Recent studies have explored novel strategies to enhance the stability of CsPbI₂Br against moisture, heat, and light-induced degradation.
- Surface passivation techniques, interface engineering, and encapsulation approaches have been investigated to mitigate degradation mechanisms and improve device lifetimes (Jin et al., 2024).

3.11.2- Defect Engineering

Defect Control:

- Defect engineering has emerged as a critical research focus for optimizing the performance of CsPbI₂Br-based devices.
- Strategies such as precursor engineering, post-treatment methods, and defect passivation have been employed to reduce trap densities, enhance charge carrier lifetimes, and improve device efficiencies (Han et al., 2021).

3.11.3- Tandem Solar Cells

Tandem Cell Integration:

- The development of tandem solar cells incorporating CsPbI₂Br has garnered significant interest for achieving high efficiency and spectral coverage.
- Tandem architectures leveraging CsPbI₂Br's narrow bandgap and broad absorption spectrum, in combination with wider bandgap perovskites or silicon, have demonstrated enhanced power conversion efficiencies and improved stability (Duan et al., 2021).

3.11.4- Large-Area Deposition Techniques

Scalable Fabrication Methods:

- Scalable deposition techniques compatible with large-area manufacturing have been explored to facilitate the commercialization of CsPbI₂Br-based devices.

- Solution processing methods, including blade coating, slot-die printing, and spray coating, have been optimized to achieve uniform, high-quality CsPbI₂Br films over large areas, enabling cost-effective production of optoelectronic devices (Han et al., 2021).

3.11.5- Emerging Applications

Beyond Photovoltaics:

- Beyond photovoltaics, CsPbI₂Br has shown promise in other optoelectronic applications such as light-emitting diodes (LEDs), photodetectors, and X-ray detectors.
- Research efforts have focused on tailoring CsPbI₂Br properties, optimizing device architectures,

4- Conclusion

In this comprehensive review, we have explored the electrical and optical properties, synthesis methods, stability considerations, comparative analysis, challenges, and recent advancements of CsPbI₂Br and its variants. Through a detailed examination of the literature, it is evident that CsPbI₂Br holds immense potential for various optoelectronic applications, including solar cells, light-emitting diodes (LEDs), photodetectors, and beyond. The unique properties of CsPbI₂Br, such as its narrow bandgap, broad absorption spectrum, and tunable optoelectronic characteristics, make it an attractive candidate for next-generation optoelectronic devices. However, several challenges, including stability issues, defect engineering, material processing, and device integration, must be addressed to unlock its full potential. Recent advancements in CsPbI₂Br research have made significant strides in improving stability, optimizing device performance, and exploring novel applications. Strategies such as stabilization techniques, defect control, tandem cell integration, scalable fabrication methods, and emerging applications have propelled CsPbI₂Br research toward practical implementation. Looking ahead, continued research efforts focusing on addressing current limitations, advancing materials synthesis and processing techniques, and exploring new applications will be crucial for accelerating the commercialization and widespread adoption of CsPbI₂Br-based optoelectronic devices. With ongoing innovation and collaboration across multidisciplinary fields, CsPbI₂Br is poised to revolutionize the landscape of optoelectronics and contribute to the development of sustainable and efficient energy technologies. This review serves as a comprehensive resource for researchers, engineers, and stakeholders interested in understanding the current state-of-the-art, challenges, and future prospects of CsPbI₂Br and its variants in the rapidly evolving field of optoelectronics.

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Antifungal effect of 4 plant species against aflatoxin production of *Aspergillus flavus*

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Abstract:

The contamination of agricultural and food products with saprophytic fungi producing carcinogenic toxins is one of the main concerns of manufacturers, distributors and exporters of these products; on the other hand, the use of chemical compounds is not possible due to adverse effects on the environment and the consumers. The most harmful mycotoxins in agricultural products are produced by species belonging to the genus *Aspergillus*, *Penicillium* and *Fusarium*. Among these three genera, species belonging to the genus *Aspergillus* are the most important toxin producers in the country. In the present study *Aspergillus flavus* as the most important factor in aflatoxin production was studied. In this project, 4 Iranian herbs were screened. The total extracts of plants were evaluated against the production of aflatoxin and finally, the most effective fraction was selected.

Keyword: Herb, Aflatoxin Test materials and methods

Preparation of total extract from plant samples

The amount of 50 grams of prepared plant powder along with 250-500 ml (depending on the plant tissue, the amount of solvent used to saturate each sample is different) methanol was poured into the separating funnel and placed at room temperature for 72 hours, so that Every 24 hours, the obtained extract was poured into a 1-2 liter Erlenmeyer flask, and fresh solvent was added to the sample again. The total extract obtained in 3 times of extraction was filtered using Whatman No. 1 filter paper and concentrated by a rotary evaporator at a temperature of 45 °C and it was kept under the hood at room temperature for 24-48 hours to dry completely. The dried extract was weighed and stored at 4°C until microbial tests

Preparation of a series of extract dilutions

To prepare the stock, first, 100 mg of each extract was dissolved in 10 mg of 5% DMSO with the help of ultrasonic waves (the obtained dilution was 10 mg/ml), the next series of dilutions (5, 2.5, 1.25 and 0.625 mg/ml) was prepared by using stock and adding sterile distilled water in the test tube. Rovral ST fungicide with a concentration of 0.5 mg/ml was also considered as control

Preparation of spores

To prepare spores, the desired isolates were cultured on CYA medium (Dox Czapek agar) at 27 degrees Celsius for 7 days in 9 cm Petri dishes by adding 5 ml of sterile distilled water containing 0.5% Tween 20 to the plates containing the fungus in Sterile condition, conidia were gently removed by scalpel. The conidia suspension was smoothed using a sterile cloth with a soft texture and the spore concentration obtained was prepared using a neobar slide (Hemocytometer Superior Germany) by adding sterile distilled water at the rate of $2-3 \times 10^6$ spores per milliliter.

Preliminary measurement of the inhibitory power of vegetative growth and toxin production of *A. flavus* by the extracts using the Macrodilution method

5 and 10 mg/ml dilutions of all extracts studied in this part of the project were prepared in test tubes containing 5 ml of YES culture medium. The spore suspension of the desired fungus, *A. flavus*, was added to each tube in an aseptic

environment so that the final dilution equal to 10^6 spores per milliliter of the mixture of extract and culture medium was obtained. Tubes containing culture medium with fungus and without extract were considered as negative control and tubes containing fungus and ST Rovral fungicide were considered as positive control. From each dilution of extract, 3 tubes were considered as replicates. The tubes were placed in a dark incubator at 27°C. The extracts that were able to control the vegetative growth of the fungus at a dilution of 5 mg/ml were selected for further evaluation at lower dilutions.

To evaluate the inhibitory power of the extracts in controlling toxin production, 2 ml of a mixture of chloroform and acetone with a ratio of 15:85 (volume/volume) was added to the contents of all the tubes, the tubes were vortexed several times during half an hour. The lower chloroform phase was removed with the help of a micropipette and after passing through a filter paper, it was poured into 50 ml beakers and placed in an oven at 40 degrees to dry. Then, 500 microliters of methanol was added to the mixture with the help of a micropipette, and its contents were washed well and transferred to 3 ml dark-colored glass vials until the time of TLC test.

Identification of 1AFB by TLC method

TLC was performed using Merck aluminum plates 20x20 cm, silica gel 60 F254) with mobile phase toluene 15% chloroform 75% acetone 10% v/v to measure aflatoxin. 10 microliters of each of the standards and 20 microliters of each unknown and control sample were spotted at the bottom of the TLC plate and then placed in the mobile phase tank at room temperature for 15 minutes. Then the plates were observed under UV light with a wavelength of 254 nm.

Analysis of research findings

Various methods including the use of chemicals such as ammonia, acetic acid, formic and propionic, fungicides and also the use of food preservatives with the help of physical and biological methods to control the growth and biosynthesis of mycotoxins have been used so far, which have either been unsuccessful or require Spending money and using special equipment. For this reason, the use of plant compounds, especially secondary metabolites, is an opportunity to prevent the use of chemicals in food (Chelkowski). In most previous studies, plant essential oils have been used to control toxin-producing fungi, including the research results on plant essential oils. Indian cloves on *Aspergillus niger* (Reddy) Screening of different plant compounds has shown that the non-polar compounds present in the hexane and ethyl acetate fractions of two *Ruta graveolens* and *Zataria multiflora* species have the greatest effect in controlling toxin production by this species of *Aspergillus*. In a recent report, the acetone extract and chloroform of Indian cloves were able to prevent the growth of *A. Flavus* and *A. niger* isolated from black tea compared to other fractions. Also, the acetone extract of this plant completely prevented the production of aflatoxin by both species of fungi. In a study conducted by Passone, the antifungal effect of *Thymus vulgaris* essential oil against aflatoxin-producing strains of *Aspergillus flavus* and *A. parasiticus* was proved on peanut. Experiments also showed that the extracts of these plants had great effects on the control of aflatoxin producing strains. In an investigation of the antifungal effect of Indian clove essential oil *Syzygium aromaticum* and *Thymus vulgaris* garden thyme against aflatoxin producing strains including *Aspergillus flavus* and *A. parasiticus* was investigated on peanuts and the results obtained from the experiments showed that the extracts of these plants had great effects on the control of aflatoxin-producing strains (Passone). In another study, aqueous extracts of 52 plant species from different families were studied against eight important *Aspergillus* species. Among the eight species, *A. niger* has the highest sensitivity to the aqueous extract of *A. nilotica* and *P. juliflora*, *M. elengi*, *L. inermis*, *Eu. globulus*, *E. officinalis*, *M. zapota granatum* (Satish) showed in another study that the essential oil of *Satureja hortensis* showed strong antifungal effects against *A. flavus*, so that the MIC of the essential oil of the target species was 25.6 µl/ml, while its methanolic extract had no Antifungal activity against *A. flavus* did not show (Dikbas) In another study conducted by Sanches on the effect of the methanol extract of *Agave asperifolia* and *A. striata* flowers, the studied extracts showed good antifungal activity against *A. flavus* and *A. parasiticus*, so that the MIC for *A. asperifolia* extract in Against the fungus *A. flavus*, 0.5 mg/ml and in contrast to *A. parasiticus*, it was 1 mg/ml. In most of the reports, the effect of the essential oils of plant species on the growth and production of toxins by different fungal species has been studied, but the published reports on the effect of plant extracts are less visible.

The results of determining the inhibitory power of extracts against toxin production by *A. flavus*

All the extracts tested at this stage were checked against the ability to produce aflatoxin. The results are listed in the attached table

	5	2.5	1.25	0.625
Achillea millefolium	+	+	+	+
Berberis Vulgaris	+	+	-	-
Mentha Longifolia	+	-	-	-
Zingiber Officinale	+	+	+	+

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Donkey's Milk; A Novel health-promoting Dairy: A Scoping Review

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ABSTRACT

Today there is a growing interest in donkey milk (DM) for human consumption due to its nutraceutical properties and presumed health benefits. The present study undertakes a scoping review to determine the extent of available information on DM beneficial properties, as well as any health hazards. Besides that, this study will compile data on the known characterization of DM, which help in making a more complete picture of both its strengths and weaknesses. A comprehensive data search was performed through the following databases using the relevant terms: PubMed/Medline, Scopus, EMBASE, and Science Direct. The papers from 1992-2023 were identified and screened.

Investigating the current evidence indicates that donkey milk proteins are more similar to human milk than cow milk which makes it a good substitute for those with cow's milk protein allergy. In addition, DM is shown to have some antioxidant, antimicrobial and anti-inflammatory properties. We identified 5 studies. The overall data suggest some favorable effects of ginger in migraine treatment. Ginger could promote a reduction in pain severity and migraine-associated symptoms. Also, ginger was well tolerated in the most patients.

Although the majority of studies support using DM for CMPA the low-fat contents of DM must be adjusted in babies fed only by DM. Besides, more controlled trials are needed to evaluate the long-term safety and efficacy of DM. In conclusion due to its tolerability donkey milk could be used as a dietary supplement, in conjunction with a balanced diet, particularly for the elderly.

Keywords: Donkey's milk, Dairy, Protein allergy

1.INTRODUCTION

Donkey (*Equus asinus*) milk has been known as a therapeutic option since ancient times [1, 2]. But today it is becoming more popular due to its beneficial properties and components. Nowadays donkey milk (DM) is available as a beneficial product for general consumption on the market and a wide range of people from newborns with allergies to cow milk to elderly people are the customers for it [1, 2].

Furthermore, various biological activities of DM have been identified in recent studies such as anti-microbial, anti-viral anti-inflammatory [3], and antioxidant activities [4]. And also, some health-promoting effects on cardiovascular health, immune system, bones, and teeth have been reported [3, 5]. Studying the characterization of DM's main constituents has shown a significant similarity to human milk and only the fat content of DM is lower [6]

In addition, the specific protein composition of DM [7], makes it a good substitute for cow milk in infants with Cow's milk protein allergy (CMPA), which is defined as an adverse immunological reaction happens to one or more milk proteins [8].

However, the available literature in this context is limited. The present study undertakes a scoping review that systematically investigates the available research in this context to make a clear picture of the potential benefits of DM, as well as the hazards. And to answer that whether can these biological activities make DM a new therapeutic option or not?

19. METHODS

The present study conducted using PRISMA Extension for Scoping Reviews (PRISMA-ScR), and the final protocol was registered prospectively with the Open Science Framework on 15 October 2020 (10.17605/OSF.IO/4HRXU).

2.1 Search strategy

To find the relevant papers an electronic data search was performed by two authors (S.R and MK) through the following online databases: PubMed/MEDLINE, Scopus, EMBASE, and Science Direct. To have an accurate search, the usual keywords were searched alone, and together with MeSH terms. As an example, the keyword “donkey” translates to MeSH terms such as “mule” or “Equus asinus”, and “milk” translates to "milk, human". Then Mesh terms together with simple keywords were used to making syntaxes for the final search. The final used syntax was as follow: ("equidae"[MeSH Terms] OR "equidae"[All Fields] OR ("equus"[All Fields] AND "asinus"[All Fields]) OR "equus asinus"[All Fields] OR ("equidae"[MeSH Terms] OR "equidae"[All Fields] OR "mule"[All Fields]) OR ("donkey s"[All Fields] OR "equidae"[MeSH Terms] OR "equidae"[All Fields] OR "donkey"[All Fields] OR "donkeys"[All Fields]) OR ("equidae"[MeSH Terms] OR "equidae"[All Fields] OR "asses"[All Fields])) AND ("milk, human"[MeSH Terms] OR ("milk"[All Fields] AND "human"[All Fields]) OR "human milk"[All Fields] OR "milk"[All Fields] OR "milk"[MeSH Terms]).

2.2 Study selection

All the article citations were entered to Endnote (Endnote X8) and duplicate articles were excluded. Study selection was conducted by two authors (SR and MK) jointly. Articles were evaluated by titles and abstracts and the unrelated papers were excluded. Then the remaining articles were evaluated by full-text and the papers that didn't meet the inclusion criteria were excluded. The inclusion criteria were as follow:

- i. Published from 1992 to 2023.
- ii. The studies evaluating the components of DM.
- iii. The studies comparing nutraceutical components.
- iv. The studies evaluating any beneficial health effects of DM.
- v. The studies evaluating any harmful health effects of DM.

2.3 Data charting

A data charting spreadsheet was developed using Excel (Microsoft® Office Professional Plus 2016). Two authors charted data from studies jointly. Data items included the general characterization of the studies (Author, Date, title of study, etc.) and outcomes (based on the type of study), key findings, and conclusions. Three data charting forms were used for three types of studies (i.e., Trial, Experimental, and Review).

2.4 Synthesis of results

The included papers were grouped by the type of study (e.g. reviews, trials, etc.). And the general characterizations of studies were summarized for each group, as well as the main outcomes of studies (which depends on the type of study) were extracted. Also, keywords were extracted which helped us grouping the studies by the outcome/benefit the measured.

20. RESULTS

3.1 Study selection

In the electronic search, 1171 articles were identified as follow:

- i. 612 from PubMed/MEDLINE
- ii. 389 from Scopus and Science Direct
- iii. 170 from EMBASE

After having removed 351 duplicates, the remaining articles were evaluated based on title and abstracts and 561 of them were excluded. The remaining articles were evaluated by full-text and 150 of them excluded as they didn't meet the inclusion criteria (Fig1). Finally, 34 studies were included in the present study.

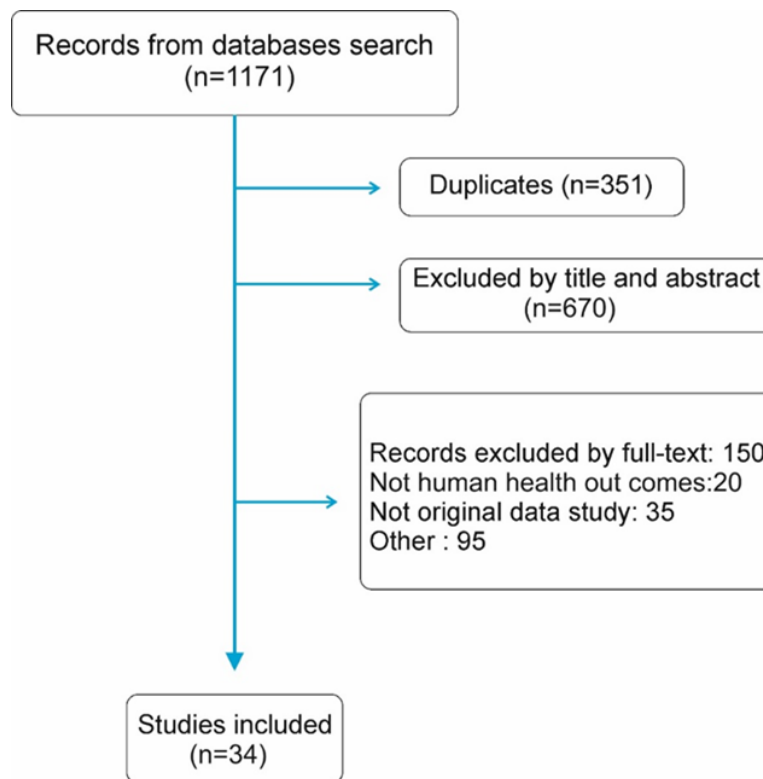


Fig. 1. The study selection process

3.1.2 Results of the studies

First, the studies (n=34) were grouped by the type of them, in which 14 experimental, 7 trials, and 8 review studies were identified. In each group, the data of the studies were extracted and abstracted. The extracted data was based on the type of study.

3.2 The main compositions of DM: Quality and quantity

3.2.1 Protein

The total protein content of human and donkey milk are reported nearly similar (0.9-1.7 and 1.5-1.8 g/100g, respectively) which both are lower than cow's milk (3.1-3.8 g/100g) [9, 10]. Besides the similar total protein content, the protein fractions of the human and donkey milk are also similar. In fact, human and donkey milk, have more whey proteins and fewer caseins, compared with cow's milk, which has more caseins and fewer whey proteins [6, 11]. Milk caseins are found in four fractions: alpha S1 (α S1-casein), alpha S2 (α S2-casein), beta casein (β -casein), and K casein (κ -casein). In cow's milk, caseins represent up to 80% of total protein content, which are mostly α S1 and β -caseins [6]. Whereas, in humans [11] and donkeys [12], caseins make up 35% and 50% of all proteins in the milk, respectively. As mentioned above, human and donkey milk, have more whey proteins compared to cow's milk (about 0.76, 0.64, and 0.57 g/100g) [2, 13].

Beta-lactoglobulin (β -lactoglobulin), a globular protein that belongs to the family of lipocalin proteins, and is known to be rich in lysine, leucine, glutamic acid, and aspartic acid [14]. β -lactoglobulin has several nutritional and functional properties. β -lactoglobulin is known to have the ability to bind specific nutritional molecules and serve as a protective matrix during digestion, such as vitamins and cholesterol [15]. β -lactoglobulin contents in cow's milk and donkey's milk are similar (0.32 and 0.27 g/100g, respectively), but is absent in human milk [16-18]. On the other hand, alpha-lactalbumin (α -lactalbumin) content is higher in human milk (0.34 g/100g) compared to donkey's milk and cow's milk (0.21 and 0.125 g/100g, respectively) [17, 19].

Lysozyme (LZ) is a natural and powerful antimicrobial enzyme that is present in body fluids [20]. Two isoforms of lysozyme are found in donkey's milk: lysozyme A and lysozyme B [21]. Lysozyme content is higher in donkey milk compared to human milk, while is missing in cow's milk [21, 22].

3.2.2 Lipid

Among the macronutrients, the most difference between donkey milk and human milk is in terms of lipid content. The average fat content of donkey's milk has been reported at 1.21% while it has been reported at 3.48% and 3.38% in cow's milk and human milk, respectively [3, 23, 24]. This lower lipid content gives donkey's milk a lower energy value of 1000 KJ/kg than cow's milk and human milk [2, 6, 25].

Studies have shown that the size of fat globules in donkey milk is very small and about smaller than half of the average globule size in ruminant milk. The small size of fat globules provides a larger surface available for the lipase action, and thus higher digestibility of donkey milk [26]. Lipid fractions in donkey milk are more similar to human milk compared to cow's milk. Saturated fatty acids (SFAs) content of donkey milk fat (57 g/100g of fat) are lower than cow milk (about 71 g/100g of fat) and more similar to human milk (45 g/100g of fat) [11, 27, 28]. Unsaturated fatty acids (UFAs) content of donkey milk fat are also similar to human milk but on the contrary to SFAs, higher than cow's milk [11, 27, 28]. Donkey milk provides a lower content of SFAs compared to human and cow milk, and although donkey milk has higher amounts of UFAs, the low-fat content of donkey's milk leads to a total intake of UFAs lower than human and cow milk.

Linoleic acid (C18:2n6 LA) content of donkey milk is similar to human milk (about 9.5 and 12.29 g/100g of fat, respectively), and higher than cow milk (about 2.05 g/100g of fat) [28, 29]. Donkey milk is a rich source of α -

linoleic acid (C18:3n3 ALA) (about 7.25 g/100g of fat), which is higher than both human and cow milk. In addition, donkey milk has high amounts of EPA compared to human and cow milk, however, the DHA content of donkey milk is lower than human milk. Based on the mentioned characteristics of fat content in donkey milk, the lipid intake must be adjusted, particularly in exclusive-milk fed babies [30].

3.2.3 Lactose, vitamins, and minerals

Lactose is a disaccharide formed by glucose and galactose. Lactose is one of the factors that contribute to calcium and phosphorus absorption by stimulating intestinal absorption [31]. Lactose is highly present at 6.5 g/100g and 6 g/100g in human milk and donkey milk [32, 33], respectively which are much higher than lactose in cow milk at 4.6 g/100g [34].

Based on the results of the studies that evaluated vitamins in human, donkey, and cow milk. Donkey milk is rich in Vitamin C (5700 µg/100 ml) but there are lower amounts of Vitamin A and E compared to cow milk [18]. Also, higher Vitamin D concentrations have been observed in donkey milk compared to cow milk and human milk [27, 35].

The ash content in donkey milk is more similar to human milk (0.36% and 0.22%) than cow milk (0.76%). Other minerals content such as calcium, phosphorus, and magnesium in donkey milk is somehow between the human and cow milk [36].

Table 1. Characteristics of the included studies

Milk Characteristics	Human	Donkey	Cow
Proteins (g/l)	9-19	14-20	30-39
Fat (g/l)	21-40	3-18	33-54
Lactose (g/l)	63-70	58-74	44-56
Ash (g/l)	2-3	3-5	7-8
Energy (kJ/l)	2843	1607-1803	2709-2843

3.3 Potential applications

Cow's milk protein allergy mostly occurs in childhood and its prevalence among children below the age of 3 is about 3% [37]. The available therapy for CMPA is to eliminate cow's milk proteins (CMP) from the child's diet. Extensively hydrolyzed formulas (eHF) are the most recommended substitutes of CMP. However, they are not tolerated by all CMPA patients [38]. Other options such as amino-acid formulas have an unpleasant and bitter taste, and although soy protein-based formulas showed to have a better taste, however, they are not recommended due to their potential to evoke allergic reactions [39]. DM has shown to be a good substitute for CM in children with CMPA, mostly due to its nutritional similarities with human milk and excellent palatability and tolerability [40]. As the study of the analysis of DM protein profile by Polidori was confirmed too [7]. Although there is not an RCT evaluating the impacts of DM in the diet of children with CMPA, such effects have been reported from several trials. Four nutritional-trials evaluating DM consumption in children with CMPA are summarized in table 2.

Reference	Year	Design	n	Aim	Conclusion
Lucrezia Sarti [41]	2019	nutritional trial	81	the nutritional impact of DM on the diet of children with CMA in term of children growth	DM resulted safe in terms of health and hygiene risks and nutritionally adequate: no negative impact on the normal growth rate of children was assessed.
Riccardina Tesse [42]	2009	cohort	25	This prospective study investigated tolerance and nutritional adequacy of AM in children with CMPA from Southern Italy	Our data confirm the high rate of AM tolerability in children with moderate symptoms of CMPA. Moreover, we found that AM seems to have nutritional adequacy in subjects with a varied diet.
Monti G[43]	2007	trial	46	investigated tolerance of donkey's milk in a population with cow's milk protein allergy, for whom it was not possible to use any cow's milk substitute	Our study found DM to be a valid feeding solution in a selected population of children with CMPA, for whom SF, eHF, and AAF could not be used to replace CM and who, because of their concomitant MFA, required a substitute food that was palatable and tolerated, as well as being nutritionally valid.
A. CARROCCIO [44]	2000	follow-up	21	To evaluate the clinical characteristics of patients with HP-intolerance and the long term outcome of treatment with ass' milk	Donkey's milk was found to be a valid alternative to both IgE-mediated and non-IgE-mediated cow's milk proteins allergy, including in terms of palatability and weight-height gain.

Abbreviations: CMA: Cow's milk allergy; AM: Ass's milk; SF: soy-protein-based formulas; EHF: Extensively hydrolyzed formulas; AAF: amino-acid formulas; MFA: multiple food allergies; IgE: Immunoglobulin E.

3.4.2 Bioactive properties

Bioactive proteins and peptides existence in DM, result in several bioactive properties such as anti-bacterial [45-47], anti-viral [48, 49], and anti-inflammatory [50, 51] activities.

- * Lysozyme: Natural anti-microbial agent, High anti-bacterial activity
- * α -Lactalbumin: Anti-microbial function, Anti-Inflammatory function
- * β -Lactoglobulin: Enzyme regulation
- * Lactoferrin: High anti-bacterial activity, Anti-Inflammatory function
- * Lactoferricin (derived from Lactoferrin): Potent anti-bacterial, anti-viral, and anti-fungal activity
- * Lactoperoxidase: Natural anti-microbial agent
- * Lactoperoxidase: Natural anti-microbial agent

21. DISCUSSION

Breast-feeding has known as the safest feeding method for the newborn mammal [52], and human milk is the best milk for human infants providing nutritive and non-nutritive factors for promoting healthy development [53, 54]. But nowadays and in many situations, breastfeeding might not be possible which warrants the need for a safe and efficient substitute [55]. Besides that, milk is an important source of required nutrients in the elderly [56].

Donkey milk is known to have closer composition to human milk compared to ruminant milk. It has similar protein content and profile to human milk, as well as, similar vitamin C and minerals contents. recent in vitro studies have shown that the beta-lactoglobulin existing in donkey milk has higher digestibility than cow's milk [57]. Also, studies suggest that in vitro the digestibility of casein and whey proteins are higher in donkey milk compared to cow's milk [58]. Also, the small size of the fat globules of donkey milk increases its lipid digestibility.

The higher lactose contents in donkey milk compared to cow's milk increases its palatability [2], which makes it more acceptable among children. Besides that donkey milk has shown to be a good substitute for cow's milk in children with CMPA [40] due to its good tolerability.

22. CONCLUSION

Compared to others, donkey milk was found to be closest to breast milk. Also, its anti-inflammatory, antitumor, hypolipidemic activities are proven in experimental models, as well as its good tolerance in CMPA. Due to the mentioned evidence, DM could be used as a supplementary diet for the elderly and also a good substitute for cases with CMPA. However, the low-fat content of DM is somehow problematic and must be adjusted in babies with exclusive milk feeding. Finally, it is advisable that the current scientific knowledge should be improved by official controlled trials.

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The use of digital technology as part of the consolidation of lexical memorization in languages: The Ankara University Private Foundation & Anatolian High School (ANKU) in Ankara

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ABSTRACT

Through this study of the lexicon in learning English as a foreign language, we see that learning the lexicon is a sine qua non for learners since it is thanks to it that they will access effective communication. Also, the integration of digital technology in the teaching-learning of languages is not new, but the web and the great diversity of tools that are increasingly easy to use seem to have had an accelerating effect. So, this research took place in The Ankara University Private Foundation & Anatolian High School (ANKU) in Ankara for the use of digital technology in the context of consolidating lexical memorization in languages. Based on this research, we will ask the question of the effectiveness of memory replays via digital technology in the context of a consolidation of lexical memorization in the medium term versus the use of paper supports. The experiment was carried out in an establishment whose students mainly have a relatively high socio-economic profile. This is a Secondary class, with heterogeneous levels. We will highlight here the fact that in English lessons, students have used the Socrative online exerciser on several occasions since the start of the year on a computer in the computer room for formative assessments (as training and self - evaluation) preceding summative evaluations on paper and that they were therefore accustomed to this digital medium during the experience.

Keywords: digital technology, lexical memorization, Ankara University Private, Anatolian High School, Ankara

23. INTRODUCTION

While the school was previously perceived by students and families as possessing digital tools and the knowledge to use them, it is clear that learners today seem more in touch with digital technology in their personal lives than in the school setting and that they develop uses of increasingly sophisticated tools. Some consider this development as a “revolution”, like the philosopher Michel Serres who goes so far as to describe this advent of digital technology as the third “anthropological rupture” following the invention of writing and communication. Printing which also led to a change in perception of space and time and a necessary re-evaluation of the act of teaching (Assailly, 2022 :10-12).

While a significant number of language teachers underline the difficulty of students acquiring a "minimal" vocabulary allowing them to express themselves, (some going so far as to admit to having abandoned any evaluation of learning vocabulary following the poor results of past attempts and the students' perception of memorizing items as boring), we are allowed to wonder about the possible contribution of the use of digital technology in the teaching of lexicon (Bin Saran, 2024). While the computer equipment available in establishments often appears insufficient given the number of students and the needs of teachers, we are led to a second question: students who are widely equipped with connected mobile phones or "smartphones", could they make this tool an asset for their language learning?

After looking at the contributions of cognitive sciences concerning the functioning of memory and what the term “digital” covers, we will consider what a work environment integrating these new tools connected via BYOD (Bring Your Own) can be. Device or use of learners' personal equipment). Based on this research, we will ask the question of the effectiveness of memory replays via digital technology in the context of a consolidation of lexical memorization in the medium term versus the use of paper supports. To this initial question will be added that of knowing whether the tool used – computer provided by the establishment or BYOD (that is to say in this case, the student's mobile phone) – can have an influence on memorization. To try to answer this question, we will present the results of the experiment carried out this year with a Secondary class. Finally, we will compare the results and the nuances that must be brought to them due to the experimental conditions while raising the questions which seem to us to be the most relevant and which in our view deserve broader investigations.

1-1 Literature review

The sources, namely books, articles, journals, theses and dissertations, used in this research are all linked to the exploration of the use of digital technology in the context of the consolidation of lexical memorization in languages. Here, some of the most important research is detailed.

According to Kosharna and al. (2023) digital and multimedia technologies are a key element in the effectiveness of learning a foreign language, as they contribute to the acquisition of innovative knowledge and the realization of educational ideas. Digital technologies improve students' philological and communicative skills. Learning a foreign language should be based on the use of an individual approach to learning, which affects the personal development of students. Emphasis should be placed on speaking, listening, writing and reading, taking into account specific trends in the development of digital technologies.

In "reviewing and exploring innovative and ubiquitous learning tools in higher education" (, 2020) Aljawarneh study that there is a negative aspect associated with the use of these applications described. For example, there is concern that by engaging students with portable devices with Internet access, they may become distracted by unrelated topics, ultimately compromising the effectiveness of such learning. Over-reliance on mobile devices can hinder students' cognitive activation. Since students have constant access to information on their smartphones, they may not make an effort to memorize the necessary material. Additionally, students are often distracted by social media conversations and browsing non-academic websites, impacting their engagement during classes.

Antufi eva and al. in 2023 concluded that the use of digital technologies in learning a foreign language contributes to the development of professional skills. The digitalization of learning also improves the organization of the learning process. Reading skills develop during the first year of study, therefore it is necessary to ensure the possibility of meaningful perception of information. Digital technologies provide syntagmatic segmentation of sentences, which contributes to the formation of correct intonation when reading.

In the recognition of coordinative compound words by learners of Chinese as a foreign language: A mixed methods study (2021), Jing Sun, Hye K. and Haiyang Ai insisted that learning Chinese as a foreign language requires coordination work, which can be implemented using digital technologies. The identification of words and their written pronunciation must be ensured during the learning process. For this, the study of inter-symbolic orthographic and semantic relationships is necessary, which excludes confusion with individual words. Digital technologies contribute to the study of semantic similarities between words and to the study of orthographic similarities. This promotes the development of students' thinking through the search for logical connections between words.

1-2 Problematic

The process of semantic memorization revealed by cognitive sciences demonstrates the importance of frequent memory repetitions for the consolidation of memorization of “essentials” via active approaches such as testing. Therefore, it seems interesting to question the place of digital technology in this process and the opportunity it represents when it is integrated into an approach demonstrating global coherence between methods, tools and educational objectives. This question can be coupled with a second question linked to the tools used and the possible place of Bring Your Own Device in class. We will therefore be led to question the effectiveness of memory recovery via digital technology (and more precisely via the Socrative exerciser) as part of a consolidation of lexical memorization versus the use of paper supports. To this initial question will be added that of knowing whether the digital tool used – computer provided by the establishment or BYOD (that is to say in this case, the student's personal mobile phone) – can have an influence on this memorization.

We will start from the following hypotheses to compare them with our experience:

1. The use of digital technology has no impact on the consolidation of memorization of the lexicon via memory repetitions; the use of digital technology via the use of the Socrative exerciser would only constitute, according to Puentedura's SAMR model, a Simple substitution for paper exercises.
2. The use of digital technology via the Socrative exerciser constitutes an Improvement or even a Modification in particular due to the motivation generated by the tool but also due to the immediate feedback which reinforces the understanding of the error and memorization among the student. pupil. The use of digital technology has a positive impact compared to the use of paper. The fact of using computer or BYOD does not impact the results.
3. The use of Socrative via BYOD, in addition to presenting advantages in organizational terms for the teacher and the establishment, leads to better results due to the systematics acquired by the students with the tool as well as the affect linked to the object.

1-3 Method

In order to refute or confirm these hypotheses, the following experiment was set up within the Ankara University Private Foundation & Anatolian High School (ANKU) in Ankara.

1-4 Participants

The experiment was carried out in an establishment whose students mainly have a relatively high socio-economic profile. This is a Secondary class of 26 students, at heterogeneous levels (from A1+ to B2), mixed with a majority of boys (9 girls, 16 boys). We will highlight here the fact that in English lessons, students have used the Socrative online exerciser on a computer in the computer room on several occasions since the beginning of the year for formative assessments (as training and self-assessment -evaluation) preceding summative evaluations on paper and that they were therefore accustomed to this digital medium during the experience.

1-5 Material and procedure

The Ankara University Private Foundation & Anatolian High School (ANKU) in Ankara, which accommodates nearly 300 students, has three computer rooms, two with 18 stations, a third room made up of two distinct spaces with limited visibility between the two (room little used and currently under construction) offering 15 computers. The rooms can be reserved by teachers via an online platform and are rarely available. No Wi-Fi connection is available

in the establishment. As part of this experiment, we used the computer room for one session (first session) as well as the following equipment.

1-6 Questionnaire

Before carrying out the experiment, a questionnaire approved by the management of the establishment was submitted to the students (appendix 2); it had to be completed individually by the students, at home, within a week. It focused on their relationship with digital technology (in class and at home, on different tools, linked to their schooling or not). It aimed to first see what concrete experience it was possible to envisage with the class. It was also a question of seeing if it was possible to distinguish broad “typologies” of students in terms of level of equipment and appetite for digital technology. The analysis of the responses to the questionnaire made it possible to identify several points (which we will develop in the section

"Analysis") including that of the inability to conduct the experiment using BYOD with the entire class (only a small number of students being both equipped with a smartphone with unlimited connection and wishing to use their telephone in class).

1-6-1 Vocabulary discovery and memorization phase in class

The entire class was required to work in the computer room (reservable by teachers but in high demand, with 18 stations available for 26 students and a space equipped with tables and chairs facing the blackboard). The first step was to discover and memorize new vocabulary. The memorization work at the start of the course in a frontal device (space in front of the board with tables and chairs) focused on a mind map (a tool frequently used throughout the year) bringing together 14 words in English. They came from a field not studied in class (so that appetite and work on the sequence do not impact the results) and considered close to their sphere of interest: music (appendix 3). The choice of 14 words resulted from a desire to avoid cognitive overload by working on two series of 7 words (corresponding to the memory span). The words themselves were chosen so as not to be too close to Turkish or, when this was the case, to present a difference in terms of the spelling of the word (rythme / rhythm – rhyme / rhyme). Following a few minutes of personal work on the translation of Turkic words into English, a sharing phase took place on the board. The students completed and corrected their production then benefited from three minutes of silent memorization work. At the end of this time, the mind maps created by the students were given to the teacher. Another activity, linked to the current sequence, was then offered to the students.

1-6-2 Test 1: training phase on differentiated tools

At the end of the course, the students were divided into 3 groups determined based on the results of the questionnaire. We will distinguish here the supports (digital – here Socrative – and paper) and the tools (computer, smartphone, paper), the paper being in this experiment at the same time a distinct support (test not exactly identical to the digital support although it is as close as possible) and a tool different from the computer and the mobile phone.

- group 1: students equipped with smartphones with an unlimited plan and volunteering to use it in class, worked on their smartphone (on which they had downloaded the application beforehand at the teacher's request),
- group 2: students more or less equipped and more or less comfortable in the computer room (a fairly disparate group according to the results of the questionnaire) worked on paper,
- group 3: students interested in digital technology but not equipped with an unlimited plan worked on a computer.

The groups were heterogeneous in terms of the language level of the students. All were subjected to a test (combining cued recall and free knowledge recall) covering the 14 words studied at the start of the course, over eight minutes: group 2 doing it on paper, group 3 on computer and group 1 on personal mobile phone (Socrative test). The “paper” test was as faithful as possible, both in the wording of the questions and in their order, to that offered on the Socrative online software, the difference being mainly in the ability of the software to provide immediate feedback on the proposed answer. (True/false and explanation of the expected answer) and allowing those who wished to repeat the exercise several times within the allotted time (8 minutes). The test focused on understanding the meaning of the vocabulary as well as mastering its spelling. A correction to the board was made at the end of the exercise for students working on paper.

1-6-3 Test 2: on paper

A week later, a second test (also combining free recall and cued knowledge recall) was offered on paper, in the “usual” class to all students. It was distinct from the first although it included the 14 words studied on the mind map.

1-6-4 Test 3: on paper

A month later, a third test (with free recall only to avoid the bias presented by cued recalls – see Limits and perspectives) was offered on paper, in the “usual” class to all students. It was distinct from the first two, although it included the 14 words studied on the mind map. It was proposed following two weeks of vacation.

The analysis concerns the comparison of the number of errors on 14 questions relating to the 14 words studied, on the three tests according to the medium used (digital or paper) and the tools used (telephone, computer, paper) during the training phase (test 1).

2- LEXICAL MEMORIZATION: DEFINITION AND RESEARCH

Scientific advances have revealed the fact that the term “memory” actually covers multiple and complementary “memories” differing in the nature of the elements to be remembered, the retention period and the quantity of information that can be maintained (Radvansky and al. 2022: 1699-1700). Crystal Williams (2023) summarize the distinctions to be made between: sensory memory linked to the sense organs, working memory processing information for a few tens of seconds and so-called long-term memory (declarative memory bringing together “episodic memory” linked to personal history and “semantic memory” made up of facts and knowledge as well as “procedural memory” bringing together procedures and automatisms).

For our part, we will concentrate on dealing with lexical memory - and therefore the conscious memorization of usable knowledge - on semantic memory. However, if this is defined by an almost unlimited capacity, it appears subject to forgetting. As early as 1885, the German philosopher Hermann Ebbinghaus developed a hypothesis on the decline in memory retention over time which he schematized in the form of a “Forgetting Curve” demonstrating that humans tend to reduce more and more by half their memory of any new knowledge in the days or weeks following its acquisition, unless they consciously re-memorize this new learned knowledge (Wertheimer & Puente, 2021: 77&82). Far from being a passive storage in the receptacle that would be the brain, semantic memory would therefore be subject to a cognitive process which would include several phases including the encoding of information, maintenance, phases of forgetting, and consolidation. Possible through storage and recall. This is what advances in so-called “cognitive” sciences tend to prove.

2-1 Semantic memory according to cognitive sciences

Cognitive sciences, born in the 1950s in the United States, can be defined as “a set of scientific disciplines aimed at the study and understanding of the mechanisms of human, animal or artificial thought, and more generally of any cognitive system. , that is to say any complex information processing system capable of acquiring, retaining and transmitting knowledge. » (Landi, 2020: 1-2). These sciences would make it possible to better understand the functioning of memory by relying in particular on the Neuroscience and the development of brain imaging. In his course given on the cognitive foundations of school learning, Stanislas Dehaene (2014), professor at the College in France holding the chair of Cognitive Psychology, takes up one of the basic postulates of the discipline: if from the end of the 19th century, Ebbinghaus (1885) postulates that forgetting follows an exponential law as a function of time, he also indicates that forgetting depends on several factors. Loftus (1985), based on numerous data, shows that forgetting is (slightly) slower when the initial facts have been over-learned. It therefore seems possible to extend memory. The problem remains, however, that teachers and students alike do not necessarily have the metacognition necessary to optimize memorization. This metacognition is one of the objectives of cognitive sciences which aim to bring out from scientific experiments the phenomena which underlie memory in order not to rely solely on intuitions to optimize learning but on methods based on evidence.

Certainly, the debate exists on the interest of the meeting between educational sciences and cognitive neurosciences which are interested in the neurological bases of memory. Some authors (Maki, 2022) argue that the two must remain separate while others (Tardif and Doudin) are favorable to this transdisciplinary exchange. While being in favor of it, Tardif and Doudin raise the obstacles and limits of this interaction: an excessive fascination with neuroscience, abusive interpretations of research results as well as the development of false beliefs about the functioning of the brain (which

have sometimes been able to penetrate the educational environment, such as the unfounded myths of the existence of a right and left hemisphere and the use of only 10% of the capacity of our brain) (Denet and al., 2022: 21-22). On the other hand, neuroscience taken in isolation seems to contribute little to educational sciences. Having raised these reservations, it nevertheless seems interesting to the authors to establish a collaboration between neuroscience researchers, education researchers, teachers and psychologists in order to better uncover the complex links that unite pedagogy and the brain. We will follow this approach here and particularly to question the functioning of the consolidation of lexical memorization.

Patricia J. Bauer and Nicole L. Varga take up the idea that “The processes of transforming temporary patterns of activation into long-term mnemonic representations require that experiences are not only recorded in the brain but also consolidated and preserved for subsequent recovery. » (Varga, Cronin-Golomb, and Bauer, 2022). The question therefore arises of the contribution of cognitive sciences to the updating of the facilitative elements of memory consolidation.

2-2 Memory recovery and consolidation of stored data

If we take up the synthesis carried out by Stanislas Dehaene based on the results of research carried out on long-term memorization, we can establish a comparison between “distributed learning” (“spaced”, repetition of an item after a certain delay empty or including other trials) and “massed learning”, when one and the same item is presented without temporal interruption). Numerous studies demonstrate that distributed learning facilitates memory retention. This is particularly the case with regard to verbal memory (learning sentences, foreign words, etc.). And to conclude that distributing learning over several periods, spaced at least one day apart, considerably increases memory retention (Hernandez and al., 2018).

Not only does the acquisition and consolidation of memorized elements need to be distributed over time, but they require the combination of two time scales, short and long: “the more knowledge must be retained over a long period of time, the more the interval between two learning of this notion can be spaced out over time (from one to two months for retention of one year or more)” (Crystal, 2023). The brain's own rhythm of learning therefore involves thinking about “spiral” teaching using the same notions on a regular basis. The optimal interval of these repetitions will depend on various personal factors of the learner (knowledge already possessed, learning conditions and techniques) but also on the term that we envisage for retention (the longer we want a long-term recall of the information the greater the differences must be). The use of memorization software with an individualized path (such as Anki) would therefore be preferred. In the context of a class, if it seems difficult to adopt a personalized rhythm for each student, it remains possible to adopt a global schedule by taking up gaps in repeats at an expanded pace (for example, a gap double the previous one). : question the students at 1 week of initial teaching, then at 2, at 4, 8, etc...). The main thing being, even without respecting the differences, to “regularly review the data” (Hernandez and al., 2018).

This memory recovery work cannot, however, relate to too extensive a mass of information and first underlies the selection of the elements to be memorized and retrieved. The “marking of the essentials” which consists of the selection and prioritization of data, is essential to enable the building of a strategy and supports for the consolidation work. It also implies that the essentials thus identified are the subject of a clear and explicit presentation to students (for example in the form of a memorization sheet or mind map). Finally, it should allow a differentiation between the “minimum” required for all students and the “recommended” for students who can and wish to go further.

2-3 Active memory and testing

When remembering the “essentials” previously described, several studies reveal the preponderant role of an active rather than passive approach for better consolidation. As early as 1890, the American philosopher and psychologist William James wrote:

“A strange peculiarity of our memory is that facts are better imprinted there by active repetition than passive. By this I mean that during learning (by rote, for example), when we almost manage to remember something, it is better to wait and make the effort to try to remember, rather than rushing through a book. If we practice retrieving words in this way, we will probably know them next time; otherwise, we will most likely need to go look in a book again. Indeed, testing your memory makes it stronger. » (Hernandez and al., 2018). Testing yourself regularly maximizes

long-term performance. The experiments carried out by Henry Roediger and his team of researchers in 2006 are enlightening on this point: doing memory tests rather than reading the same data several times improves long-term data retention. Testing indeed has several advantages: it has a beneficial effect on the student's concentration; provides metacognitive information on the quality of their learning (are the answers provided consistent with those expected or not) which allows them to return to concepts that are difficult to memorize; finally, introducing knowledge tests would also have positive effects on the amount of information retained in the course.

As part of a test or assessment (whether diagnostic, formative or summative), there are several methods of recalling knowledge: recall by recognition (which presents a list from which to choose the correct answer(s) , multiple choice type exercises: the success rate is normally high because the correct concept is already activated), cued recall (the student must find a piece of data but a clue is given to him, for example with a diagram to complete, support proposed visual...) and free recall (where knowledge must be mobilized without assistance, this type of very demanding recall presenting increased difficulty in mobilizing memorized data). To measure memorization, it is therefore indicated, in addition to using frequent tests, to add to an evaluation of knowledge by free recall, questions with cued recall or recognition (Denet and al., 2022 : 3-9).

2-4 Role of interactivity and immediate feedback in memory consolidation

During the recall phases of facts memorized by testing, it is possible to use different methods of feedback to the learner. We can refer here to the learning theory which distinguishes three forms of learning (Hernandez and al., 2018):

- Unsupervised: no distinction is proposed between the desired inputs and outputs.
- Supervised: on each trial, the learner is informed of the answer that would have been correct.
- By reward: the learner only receives a scalar (degree of success: grade, percentage, etc.)

According to studies, supervised learning appears to be the most effective. This implies the fundamental role of feedback after each student proposal. However, the latter often receives feedback on their errors several days or weeks after practicing (after the teacher's correction). The feeling of error, which can be more or less conscious (because many feel insecure about their attempt if they perceive it as potentially false), is therefore met with a lack of response over a long period of time. Proposing immediate feedback validating or invalidating the student's proposal therefore amounts to capitalizing on the feeling of the error and the doubt it generates by explaining the error. This allows testing to be included not in the evaluation of the student's level but in the extension of the learning and memorization processes. Crystal (2023) specify that ideally the return, in addition to being rapid, should be personalized, this last point, like that of expanded intervals, being able to clash with the pragmatic conditions for implementing the returns.

3- THE PLACE OF DIGITAL AT SCHOOL

The Internet is above all a technical object: you must have the necessary equipment (network cards were not yet the norm; in Turkey, Wi-Fi was only used by a few handfuls of people), know how to use this equipment, know how to connect and, above all, know, according to the expression of the time, "surf online". The Internet is a window open to the world, even if the creation of Wikipedia dates from January of the same year and will take a few years to gain momentum. It is also an expression tool allowing you to make your publication potentially accessible to any other connected person. Having this possibility, as a teacher in a high school, meant following paths of experimentation hitherto little taken: not only did it make it possible to discover or deepen the use of 'Information and Communication Technologies', but more importantly to share information, practices, feedback between teachers (Batista, 2021: 1-2).

If we consider the term "digital" to describe anything that uses computer systems, the use of digital technology within Education is not without raising many questions. Sometimes vilified for the harmful effects it would have on students' ability to concentrate and their deleterious impact on their social relationships, its use has also been encouraged for several years to be part of the learning processes offered by Education. national.

Digital technology will make it possible to experiment with reinforced evaluation, based on better use of data and improved sharing capacities within educational communities. Students will be able to practice, self-assess, and participate in diagnostic moments based on content adapted to their levels and/or their needs. These devices will also help to relieve teachers of certain tedious correction tasks by providing them with the tools which enable them to further individualize their action with each student (Awang, 2021 :1-2).

“Digital humanities”, a notion that appeared in 2004, widely used in the academic world of research and which brings together, to use the definition used by Mounier and Dacos (2014) and borrowed from the Digital Humanities Manifesto written in 2010 in Paris (co-signed by more than 250 researchers and 10 institutions): “a transdiscipline, carrying methods, devices and heuristic perspectives linked to digital technology in the field of human and social sciences” (Fiormonte and al., 2015: 212). We will focus more modestly on a very structured use of digital technology as an element that can potentially facilitate memorization based on memory repetitions with immediate feedback. It could at best be envisaged that the experiment presented here would enable students to understand the self-training process via digital technology, a fact which will not be measured and can only remain as a supposition.

Recent work identifies four key skills (critical thinking and problem-solving, creativity, communication, collaboration) and six qualities (curiosity, sense of initiative, tenacity, adaptability, leadership, social and cultural awareness) required for 21st century job market. Among these skills and qualities, some are already at the heart of the missions carried out by the Turkey school – training citizens equipped with a critical mind, for example –, others are traditionally less valued by our education system – such as promotion of creativity or a sense of initiative (Awang, 2021).

It turns out that the digital world is largely based on these skills or offers extraordinary opportunities to develop them:

- individualize teaching: individualized teaching, based on immediate adaptation of teaching to the progress and difficulties of each student;
- use Big Data to improve the performance of the education system: the continuous assessment of students' achievements and the difficulties they encounter constitutes a major management issue for educational policies. The collection of this data could also allow the detection of learning difficulties in early grades;
- promote autonomy and creativity: adapt to a constantly changing world; by encouraging the autonomy and experimentation of each student in particular (“learning by doing”).

4- SUMMARY PRESENTATION OF THE DIFFERENT PHASES OF THE EXPERIMENT

Experiment on the use of digital technology in interaction to evaluate the contribution of digital technology in the context of medium-term memorization, thanks to memory tests by testing. Question: are we according to the Puentedura model, within the framework of a Substitution (identical results), an Augmentation (improvement of results) or a Modification (transformation of the activity)? What effect does computer or smartphone use have on memorization?

Table 1. Summary presentation of the different phases of the experiment

Phases of research	Population	Objective
Quiz	Treatment of 26 quizzes wearing on the use of digital by the students.	<p>To understand THE degree of equipment family and staffstudents.</p> <p>Assess their will to use their material own in courseof English.</p> <p>Assess the report emotional has their material.</p> <p>Spot the behaviours dominant in their relationship learning / digital.</p>

Phase test 1	<p>26 students divided into 3 groups determined based on the results at quiz and heterogeneous on the plan of language level:</p> <ul style="list-style-type: none"> - GR 1: students equipped with smartphones with unlimited plan and volunteers to use it in course: working on a smartphone (Socrative software) - GR 2: more or less equipped and more or less comfortable in the gym computer science: work on paper - GR 3: students interested in digital, not equipped in package unlimited: work on computer (Socrative software) 	<p>Work in beginning of session on A vocabulary out course (14 words - 2 x 7 words - on mind map):</p> <ul style="list-style-type: none"> - words proposed in Turkish has translate - putting in common, mind map completed / corrected by the students - 3 min of memorization in silence - the teacher raises their mind maps in warning that there will be a second test the following week but without revision (No need of their mind map) <p>Objective: memorization in class</p> <p>End of course: test of 8 min on their memorization of sense and of spelling of the words studied in beginning of course with 3 different tools: paper – computer – smartphone Objective: phase of reminder little of time After phase of memorization used as training</p>
Phase test 2	Test of all of the 26 students	1 week more late: assessment of all of their class on a quiz paper
Phase test 3	Test of all of the 26 students	1 month later: evaluation of the entire class on a quiz paper
Analysis	Analysis born wearing that on THE results of students present at the 3 phases of test: 22 students	<p>Comparison of the results (number of errors) of tests 1 (memorization + 45 min.), 2 (memorization + 1 week) And 3 (memorization + 1 month) depending on the supports and tools proposed in phase 1 (test 1) in order to put has day the effect of the brackets (digital / paper) And tools (phone, computer, paper) used in phase 1 on memorization to medium term (+ 1 week and + 1 month)</p>

5- DATA ANALYSIS

The results of the questionnaire on students' digital uses in and outside of school revealed the following points in particular:

Table 2. Data analysis

on 26 students	
<u>Equipment staff</u>	
26 students either 100%	have either of a computer staff either of a computer family either of a Tablet

22 students either 84%	use their computer staff Or family In THE frame of their studies
26 students either 100%	have A phone portable of kind smartphone
17 students either 65%	have it selected themselves
1 pupil either 3.8%	smartphone is not not connected has Internet
14 students either 54%	are connected with package limit
11 students either 42%	are connected with package unlimited
<u>Use of digital has school</u>	
14 students either 54%	se feel very has comfortable in room Computer science
10 students either 38%	se feel moderately has comfortable in room Computer science
1 pupil either 3.8%	born se feels not has comfortable in room Computer science
10 students either 38%	have Already used their smartphone in course
21 students either 80%	would be ready to use their smartphone in class: 11 without terms / 10 according to the context
3 students either 11%	do not seem ready to use their smartphone during class, 1 of which is justified by the package limit / 1 by the private aspect of tool / 1 No motivated
12 students either 46%	think it would be easier to use a smartphone rather than a computer the institution : 10 are fully convinced, 2 in are quite convinced
12 students either 46%	think that he born would be not more easy to use A smartphone instead one computer
8 students either 31%	students have both an unlimited plan and the desire to use their phone during class (+ a 9th would be All right "according to THE context") > interviewed, THE 9 students confirm their will of participate has experimentation
12 students either 46%	think that he no has not enough of digital has school
14 students either 54%	think that he y has A Good balance between brackets digital And paper has school

We can note here some surprising aspects: if the equipment with digital tools appears very good (which could be expected according to the TNS Sofres studies seen previously and the high socio-economic profile of the class), we can be surprised the large number of phones not connected or connected with a limited plan. This decisive fact decided the continuation of the experiment because it was not allowed, as initially planned, to carry out an experiment on a smartphone with the entire class due to the absence of a Wi-Fi connection within the establishment and the need to go through the connection of students.

Test 1 presents the following results (note: the data from students who were absent from one of the three phases of the experiment were not retained in the analysis proposed here, the results therefore relate to 22 students).

Only the results of the test completed the first time by the students who had the opportunity to repeat the exercise on Socrative several times were taken into account here.

Table 3. Results of the test completed the first time

Test 1 - Synthesis of number of errors according to tool	TOTAL	AVG. BY PUPIL
Socrative - Computer - 7 students	21	3
Socrative - Smartphone - 8 students	36	4.5
Paper - 7 students	18	2,571 428571

In this training phase, relatively similar results appear between work on computer and on paper, while we note a higher number of errors on smartphones. The greater number of errors on Smartphone is however to be linked to difficulties in using the tool (used for the first time in class) demonstrated by certain responses noted below (and which are not found with the use of Socrative on the computer, use to which the students were accustomed):

Table 3. Test 2 presents the following results:

Test 2 - Synthesis of number of errors depending on tool	TOTAL	AVG. BY PUPIL
Socrative - Computer - 7 students	34	4.85
Socrative - Smartphone - 8 students	32	4
Paper - 7 students	28	4

6- DISCUSSION

6.1 Context

In order to compare different methods of consolidating lexical memorization, we compared “training” work on two different media (paper/digital with Socrative software) and on three different tools (paper/computer/smartphone) in order to compare the following hypotheses to the experiment:

1. The use of digital technology has no impact on the consolidation of lexicon memorization; the use of the Socrative online exerciser would only constitute, according to the SAMR model, a simple replacement for paper exercises.
2. The use of digital technology via the Socrative exerciser constitutes an Improvement or even a Modification due to the motivation generated by the tool and the immediate feedback. The fact of using computer or BYOD does not impact the results.
3. The use of Socrative via BYOD, in addition to presenting advantages in organizational terms for the teacher and the establishment, leads to better results due to the students' habituation of the tool as well as the affect linked to the object.

6.2 Linking with research

The use of digital technology would therefore seem slightly less efficient after one week but more efficient after one month; the rate of memory loss would seem less significant with the use of Socrative. The hypothesis according to which the use of digital technology has no impact on the consolidation of memorization would therefore seem invalidated. If we refer to the writings relating to cognitive sciences studied in the first part, this could be explained in particular by the provision of immediate feedback which in addition to immediately specifying the correct answer, makes it possible to provide additional elements of understanding to the student.

As for our second hypothesis, the use of digital technology via the Socrative exerciser would here constitute an Improvement of the activity according to the SAMR model and not a Substitution (in which case the results would be

identical). On the other hand, with regard to the second point of the hypothesis on the supposed homogeneity of the results according to the two numerical tools used, we can only invalidate the point. The differences between results on computer and smartphone prove to be significant in this experiment: the number of errors is higher in the training phase (test 1) with the smartphone (which can easily be explained due to the novelty of the process tested for the first time here by the students), at one week however, the results of the “smartphone” group seem slightly better but the retention at one month appears much less good (with an average of 8.1 mistakes out of 14 words compared to 6.4 with computer). It is possible to envisage that the cognitive load generated by the use of a new tool such as the smartphone has diverted the students' attention towards the functioning of the tool rather than towards the heart of the learning (frustration generated by the typos and errors mentioned above which can be a factor of decentralization). The motivation generated by the use of this new tool would therefore see its positive effect on memorization annihilated and the novelty would even have the effect of dispersing the attention of learners.

Finally, our third hypothesis seems to be refuted by experience. If in organizational terms, BYOD presents undeniable qualities for the teacher (no need for the coveted and rarely available computer rooms), it presents major disadvantages here. We see that many students are equipped with a limited package and that the need to connect for in-class exercises comes up against this limitation. On this subject, it is possible to hypothesize that it is a choice of parents linked more to the desire to restrict their child's "digital consumption" rather than to economic considerations (the same families which can also be very well equipped with digital tools – family computer, personal computer, tablet – and the cost of unlimited packages is now close to that of limited packages). One of the conclusions to be drawn regarding BYOD could be that it is necessary for the establishment to offer a WiFi connection if it wishes to develop work on this new tool, without which the organization, instead of being facilitated, is on the contrary made more complex or even prevented. As for medium-term memorization, it does not seem to have a positive impact despite the affect and motivation associated with the smartphone tool. On the contrary, its effects seem negative, whether due to the novelty of its use (the students being used to paper and in this case, to the computer exerciser), the practicality of the tool (size of the keys causing typos and potential frustration or at least too much concentration devoted to the use of the tool itself rather than to the digital medium and its content).

Conclusion

If it seems clear from this short study that digital technology and BYOD in particular are not to be favored for memorization phases as such, it could be a valuable ally for the recall and memory consolidation phases in class or even independently. Digital technology could be one of the means that allows us to move towards what researchers such as Stanislas Dehaene (2014) are calling for: “replacing grades with a precise, differentiated, rapid assessment, which can only progress with time. child (...) and promote the child's self-evaluation. ”.

In my opinion, the use of digital media such as the Socrative exerciser has many advantages, including (which is perhaps the most important of all) that it allows the teacher to adapt his course: do a test of a few minutes on the phone at the start of the session would allow us to see if only two or three students have not integrated the necessary prerequisites to move forward (and to help them directly with individual remediation while the rest of the class works on another exercise) or if a majority of students did not know how to answer (and to make a collective reminder in order to avoid a blockage at the start of the course). Digital technology would therefore allow an improvement in formative assessment (as seen during our experience) but also in diagnostic assessment. We could therefore speak of Increased practice thanks to the digital tool which makes it possible to assess the knowledge of the entire class instantly and gives the teacher the ability to adapt his response (in order to being able to immediately and effectively differentiate one's teaching methods) which was impossible before. It is here the practice of teaching itself that is modified, “augmented”.

Finally, the teacher reassured by the simplicity of using digital testing supports such as Socrative, may be led (as is my case) to want to go further in the use of digital technology and towards the transformation of their own teaching practices.

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A Research on the Diversity of Poetic Vocabularies; Study of "Layla and Majnun" Narrative Poem in the Works of Nizami, Jami, and Amirkhosro Dehlavi Based on the Theory of Johnson

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Abstract

Persian literature's poets are a treasure of vocabulary and meanings, and their knowledge of poetry flourished. The broader the vocabulary domain of a poet is, the more various the interpretations and meanings are for the readers. One of the methods to study the vocabulary treasure of a poet is "Johnson's statistical stylistics approach" which aims to identify the poetic style and vocabulary application of a poet using mathematical science. In the present research, it is attempted to compare the "Layla and Majnun" narrative poem in the works of Nizami Ganjavi, Jami, and Amirkhosro Dehlavi using the theory of Johnson, to study the subject of lexical diversity in the poetic style of the three elected poets. In this research, it is determined that Nizami has less lexical diversity compared to the two other poets, however his poetic style resulting from the use of special and combined vocabularies in his poems has priority over the two poets which led to more popularity and durability of Nizami's "Layla and Majnun" poem. In the meantime, Jami has the highest lexical diversity and a broad meaning scope which shows the significance of his narrative poem after Nizami's aforementioned poem.

Keywords: Lexical diversity, Johnson, Nizami, Jami, Amirkhosro Dehlavi, Layla and Majnun.

1. Introduction

Persian literature is significantly integrated with other sciences such as philosophy, ethics, astronomy, medicine, mysticism, etc. In other words, to know all aspects of a literary work, the researcher must investigate it with full knowledge of various sciences because the poets and writers of Persian literature, especially the poets of the classical period, have attained sufficient knowledge and awareness in various fields and have reflected those sciences in their literary texts. Thus, literature cannot be considered separately from other sciences, and it must be acknowledged that Persian language and literature are intertwined with other sciences in the three categories of development, interpretation, and function. In the development category of literary works, it is possible to deal with topics related to sciences such as history, politics, ethics, mysticism, philosophy, and the like. In the interpretation category, there is a need for sciences such as jurisprudence, astronomy, theology, etc., to understand and interpret some texts such as the poems of Nizami and Nasir Khusraw. In the function category, we can also refer to ethics, mysticism, and the educational section of literary texts.

Since there is a deep and complex relationship between literature and other sciences, with the help of knowledge such as mathematics and statistics, many issues of stylistics and literary criticism in literature can be justified and interpreted. One of the areas where the answer to many unknown questions can be found with the help of statistics is the study and examination of the vocabulary of a poet. By identifying the limits of the words that each poet uses in their poetry, their poetic style can be understood to some extent. With the help of mathematics and statistics in stylistic research, it is possible to find out the methods of each poet in using different word formations and selecting lexical diversity. Furthermore, through a comparative study between two or more poets in this field, it is possible to find out the specific stylistic features and individual distinctions of the poets.

With the help of statistical knowledge and following Johnson's mathematical formulas, this research aims to compare the "Layla and Majnun" narrative poem in the works of three poets of Persian literature, Nizami Ganjavi, Jami, and Amirkhosro Dehlavi, with the approach of examining the diversity of poetic vocabularies. Therefore, the question we are trying to answer is, what is the style of vocabulary selection in the poetry of the selected poets and what are its special characteristics? Also, among the three mentioned poets, which one has more diverse vocabularies?

Nizami's "Layla and Majnun" is one of the most prominent romantic poems in Persian literature, which many poets have imitated at different levels, including "Layla and Majnun" by Jami and Amirkhosro Dehlavi. Studying and comparing the variety of poetic vocabularies of these three poets can guide us toward the poetic position and special style of each poet in vocabulary selection.

2. Research Background

Since interdisciplinary studies between the two fields of literature and mathematics have not been well received in contemporary research studies, thus only a few cases of the conducted research are mentioned.

"Stylistics" (1992) and "In the literary text, a stylistic study of horsemanship" (1993) were written by Saad Maslouh, who has done research in Arabic language with the help of Johnson's theory. Two articles "The Relationship between Stylistics and Statistics" (2013) and "Research on the Diversity of Poetic Vocabulary" (2012) by Ebrahim Anari and Ahmad Omidvar, as well as the article "Comparison of the poems of Forugh Farrokhzad, Farzaneh Khojandi and Khaledeh Forugh from the perspective of Johnson's theory" (2014) by Ali Asghar Bund Shahriari and Tahereh Seyedrezaei are examples of this type of research in Persian literature.

2.1. Stylistics

Stylistics is one of the branches of literary studies that nowadays deals with the extensive study of literary texts and various poems. The purpose of stylistics is not only to determine the characteristics of a work but also it seeks to find out what characteristics a work has that make it special and different from other works. In addition to the fact that the style of each poet or writer is defined in the form of characteristics that are unique to that person, the common characteristics of a group is also considered a style that has created Khorasani, Iraqi, Indian, and similar styles in Persian literature. Therefore, in the field of style, individual, social, and ethnic styles have emerged, each of which has its own unique features and characteristics.

"style" in the word Tazi means melting and pouring gold and silver, and Sabikeh means a piece of melted silver... Setil in European languages is derived from the Greek word "Stilus", which means column... Stilus in Greek is a metal or wooden instrument or ivory, which was used to engrave letters and words on wax tablets in ancient times (Bahar, 2004, vol. 1: 15-16). The terminological definition of style states: "Style is a way of using language in a certain context, by a certain person, for a certain purpose" (Leech, 1981: 10). Bahar defined the term style as follows: "Style in the literary terminology is a special way of perceiving and expressing thoughts through the combination of words, the choice of words, and the way of interpretation. Style gives a literary work its own image in terms of form and meaning and it, in turn, depends on the speaker's or writer's way of thinking about the truth" (Bahar, 1990: d).

Regarding the stylistic approach, there are two opinions, one is to pay attention only to the appearance and language of the work, and the other, in addition to paying attention to the appearance, also gives importance to the meaning and how the word and the meaning are connected. It seems that the second view is more correct about the style of each writer or poet because what distinguishes the work of an artist from the works of others is both the way of expressing words and the way of expressing meanings. What differentiates the intellectual perspective of a poet or writer from others is their use of words to express meanings because two people who talk about a single subject may use different verbal methods or use the same type of verbal method but convey different meanings. Therefore, it is not enough to summarize the style in terms of appearance and words, and the inner meanings must also be investigated. Samiei emphasized this opinion in his article and considered it to be the result of the artist's special view of the inner and outer world, which is specially presented to the audience (Samiei, 2005: 151). Shamisa believes that today the purpose of stylistic studies is not only to examine the appearance of the work and its special features but also to emphasize the importance of words in interpreting the text (Shamisa, 2007: 143).

The study of stylistics of works is not very old and can be considered an emerging phenomenon in the middle of the 19th century. The main structures of stylistics can be seen in the works of Charles Bally (1865-1945) and Leo Spitzer (1887-1960). In their works, these people expressed the main stylistic features and structures of texts and introduced them by showing different functional categories and methods (Katano, 2005: 114-115). Leo Spitzer expressed the use of words in the poet's personal style with the method of circle cognitive dictionary, in which by examining a literary text, one can understand the lexical circle specific to the poet (Shamisa, 2007:24). After the expansion of stylistic studies, theorists such as Ferdinand de Saussure and Roman Jakobson introduced various linguistic analyses into this field; But, they did not have much effect on the main structure of stylistics. Since Chomsky's transformational-

generative grammar (1957) entered the category of stylistics, the goals and main structure of this process transformed (Katano, 2005: 116). The entry of different points of view into stylistics became a factor in paying attention to the integration between meaning and words in the studies, and stylistics moved from the domain of one-dimensionality to the range of root and semantic studies.

In general, the various parts of stylistics can be divided into these categories: "Levels and units of analysis in a language that can organize a stylistic investigation include phonetic layer, lexical layer, syntactic layer, semantic layer, and pragmatic layer." Linguistic knowledge examines each of these layers with special methods and tools:

Phonetic analysis: It consists of examining the sounds of the language.

Lexical analysis: It examines the smallest meaningful units of the language, word structure, and the formation of words.

Syntactic analysis: It examines the structure of sentences and methods of combination of words in phrases and sentences.

Semantic analysis: Semantics discusses the sentence and the truth value of its meaning.

Pragmatic analysis: It examines the meaning of the word in the situation and context in which it is used. (Fotouhi, 2012: 237-238).

3. Theoretical Foundation

According to Stephen T. Grice's point of view, during the past years, linguistics has had a general position and statistical studies in its sub-disciplines such as phonology, sociology of language, and psychology of language have been very popular, while little statistical research has been done on most of its fundamental sub-disciplines, such as methodology, syntax, semantics, etc., and research started only in the 1990s. Stephen T. Grice has introduced the following method for various statistical studies in linguistics:

1- distribution, 2- frequency, 3- mean (such as average or median), 4- dispersion (such as standard deviation or interquartile ranges), and 5- correlations (such as Pearson's r or Kendall's τ) (Dmitrieva, 2015: 137-138).

Johnson is one of the theorists whose views in the field of linguistics have attracted the attention of researchers. "He believes that by counting and implementing some processes, the style of the authors can be determined in terms of the amount and manner of choosing words" (Anari and Omidvar, 2012: 38). Johnson states about the importance of statistical studies in the field of linguistics: "Linguistics as a discipline must be equipped with quantitative analysis tools to take important steps towards understanding language" (Baayen, 2008: 247).

In Johnson's research methodology, there are three important steps, which include selecting the research sample, determining vocabulary, and using computational methods in this field.

Johnson and Bains' book (2008) explains statistical tools that help the reader better understand the tools used in the linguistic subfields of phonology, language psychology, sociology of language, historical linguistics, and syntax.

This book is one of the leading books in the new era of studying linguistics, which is defined as the era of R. R is a statistical program that has been approved by the statistical community and can implement any type of process. This book is a variety of statistical ideas among linguists who are already familiar with basic tests such as correlation, T-tests, and ANOVA (Larson, 2009: 279).

Regarding the tests proposed by Johnson in his book, Larson states that this method is very useful in the field of linguistics by using real data sets and real research questions to emphasize and explain the tests. Statistics is a practical and very appropriate method that will help readers and researchers in this scope and various fields (Ibid.: 281).

Chapter 1 under the title "Fundamentals of Quantitative Analysis" presents different types of distribution (bell curve normal distribution, bimodal distribution, U-shaped distribution, etc.). Chapter 2 under the title "Patterns and Experiments" begins with an extensive discussion of the well-known statistical concept of random samples and general population, i.e. standard book information about analytical statistics is presented. Chapter 3 under the title "Phonology" is the first chapter that pays special attention to linguistic issues and in a very simple way, depicts different significant tests (T-test for independent samples and paired comparisons) and multivariate methods (multiple regression and principal component analysis). Chapter 4 under the title "Psychology of Language" deals with a limited number of psychological phenomena of language. Chapter 5 under the title "Language Sociology" is mainly dedicated to the sociological issues of language, such as data on the phonetic realization of phonemes by speakers, which depends on age, gender, etc. Different clustering methods and multidimensional scaling methods - that is, once again

multivariate statistical methods - are presented in chapter 6 under the title "Historical Linguistics" " In this chapter, mainly examples related to the (phonetic) similarity and historical connection of languages are discussed. The last chapter, chapter 7, under the title "Syntax" deals with the methods presented in the previous chapters from a statistical point of view. This chapter provides the reader with a deeper understanding of linear/non-linear regression analysis and ANOVA based on data from experimental studies (Kelih, & cutek, 2010: 75-76).

3.1. Research Sample Selection

To know the extent of the vocabulary of a poet, it is not necessary to examine all their works, but in Johnson's theory, a section is selected as a random sample and the words used in this section are calculated and examined.

This research comparatively examines the variety of poetic words used in the "Layla and Majnun" narrative poem in the works of Nizami, Jami, and Amirkhosro Dehlavi. The statistical samples of this research include three thousand words from the beginning of three selected narrative poems: "Nizami's Layla and Majnun" from page 359 to 370 of the book "Koliyat – Complete Works of Nizami Ganjavi" (2015) by the efforts of Kazem Abedini Mutlaq and "Jami's Layla and Majnun" from page 226 to 240 of the book "Mathnawi Haft Awrang" corrected by Jabalqa Dadalishah et al., as well as the book "Amirkhosrow Dehlavi's Majnun and Layla" (1964) with an introduction by Taher Ahmad Oghli Muharram Ouf from page 1 to 41.

The selection of the first three thousand words of the selected narrative poems is due to reducing the randomness factor and the sameness of the position of the verses in each poem.

3.2. Determination of Different Words

The choice of vocabulary due to the lack of a specific unit and reference requires the establishment of rules that are the same in the review of all three narrative poems. In this sense, a correct definition of the used words and their variety should be provided. "A word is one of the language units that is made of one or more morphemes. A word can have an independent meaning and concept" (Jalili, 2015: 57). Besides this kind of word, there are also words that do not have an independent meaning, such as prepositions, complements, and interjections.

In this research, the criteria for selecting words based on variety and repetition are as follows:

- Each verb is counted only once. Its various forms are considered repetition like the word "make" from which the forms "made, makes, will make, etc." are created, but they are counted only once as a lexical diversity.
 - Compound verbs and prefixes are also counted once and are considered a diversity of the main verb, like the word "come" which has a variety of "come back, come up, etc."
 - Pronouns connected with the verb are one word., e.g. "I burned, you didn't come".
 - Auxiliary verbs are counted together with the main verb of a word, e.g. "I had written"; But if they do not have an auxiliary role, they are a separate word. "The verbs that are made from the infinitives of "to be, to have, to want, to become" and their synonyms are considered auxiliary verbs when they are used with another verb and completely lose their original meaning, or only are only used to make some tenses" (Ibid.: 97).
 - Semi-auxiliary verbs are counted separately from the main verb, e.g. "I have to go".
- Semi-auxiliary or formative verbs include cases such as: to become, it is possible, it is better, it is good, it is necessary, to stand, and to be able (Farshidvard, 2012: 237).
- Sometimes there is a phonetic difference at the beginning of some words, but they have the same infinitive; For this reason, they are considered repetition, e.g. "it is, it is not, this is".
 - Some prepositions are abbreviated and become monosyllabic, in this case, they are counted together with the next word, e.g. "Az, Ze Aval, ..." ("from, from the beginning, ..."). But, when "and" is accompanied by the abbreviation of prepositions, they are considered as one word, e.g. "Vaz, Va Az", because more than one phoneme is involved in it.
 - Singular and plural states of a word are considered repetition, e.g. "attribute, attributes, ..."
 - Words that are abbreviated to each other are considered repetition, e.g. "Agar, Gar (if), Shah, Shaah (king)".
 - Words that have the same written form, but different meanings, are considered diversities, e.g. "Shir" meaning drinkable liquid and "Shir" meaning forest animal.
 - Different active and passive forms are considered diversities of the main word, e.g. "love, lover, beloved, love affair".
 - The diminutive word is diversity, e.g. "Mard, Mardak" (man).
 - The prepositional phrase is counted with the word before it, e.g. "the tree of life".
 - Ambiguous pronouns are considered independent words, e.g. "anything, anybody, anyone".

- The words with "relative suffixes" are considered diversities, e.g. "Iranian, weekly, three-year-old, salty". In cases where "Y suffix" is connected to the word of "relative" type or infinitive, it is considered a diversity along with the main word, e.g. "Abele, Abelepay" ("smallpox").
- Compound nouns and adjectives are considered as one word, e.g. "Kon Fa Yakon (annihilate), Khod Ray (opinionated), Kar Gosha (helper), Boland Bin (high-minded)".
- Different letters are considered separate words because "some letters (morphemes) are verbally independent, that is, they are used alone in a sentence or with other words, but they do not have an independent and complete meaning and are used to connect words or sentences. These letters are divided into three groups: conjunctions, prepositions or complements, and interjections" (Jalili, 2015: 262).
- Among the conjunctive adverbs, only "and" is connected to the word after it and is counted with it because it does not have a separate sound. Other conjunctions such as "but, however, yet, etc." are considered independent words.
- Placement of prepositions at the beginning of the noun creates a semantic difference and is considered an independent word. "Many compound prepositions can be made differently based on a single noun with the help of simple prepositions. A noun used in a compound preposition loses part of its semantic content" (Lazard, 2014: 100), e.g. "in the back, to the back, from the back".

3.3. The Stages of Lexical Diversity Calculations

To calculate the diversity of words in each narrative poem with the help of Johnson's theory, first, the words are separated and after screening, they are counted and calculated in statistical formulas. The three thousand initial words of each poem are divided into thirty sections, each section containing one hundred words. For this purpose, thirty tables are drawn as 10 x 10 and an independent word is placed in each row. From table (1), the review of words begins, and repeated words are crossed out and removed from the counting cycle. This process continues in other tables. In this way, if the word "key" appears in table (1) and is repeated in table (11), that word is crossed out in table (11) and is considered a repetition. After completing this step, the number of words not deleted in each table is counted and recorded.

Table (1). An example of a vocabulary calculation table.

	1	2	3	4	5	6	7	8	9	10
1	Oh	your	name	is the best	beginnin g	when	will I	open	the letter	without
2	Your name	Oh	your	memory	calms	me down	there is	nothin g but	your	name
3	On	my tongue	Oh	the helper	of everythin g	there is	your	name	is the key	everythin g
4	close d	Oh	no line	was	written	from the beginnin g	withou t	the reason of	your	name
5	Oh	the creator of	the foundatio n of	existence	no one has	the ability to	show their strengt h	Oh	God	bless
6	your	sermon	your	grace	is always	bless by	God	Oh	seven	brides of
7	nine	heaven s	are	guards	of	your	gate	Oh	You are	the knower
8	of	inside	and outside	Oh	everythin g	that	is	calm	and	peaceful
9	has been	created	in your	annihilatio n	Oh	the true	giver	of reason	and life	with

1 0	your	order	nothing	can be	different	Oh	intimate of	the world	of wonder	the world
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The number of different words: sixty-seven (Nizami, 2015: 359).

As can be seen in the above table, the word "name" appears in column 3 x 1 and is repeated in column 8 x 3, so it is removed from the word count. Also, the word "the world" appears in column 8 x 10 and is repeated in column 10 x 10, which is not considered in the second counting.

Johnson has considered four parts to calculate lexical diversity:

3.3.1. Determination of the Type Token Ratio (TTR)

In Johnson's theory, the amount of lexical diversity can be determined by calculating the number of different words in relation to the total number of words. "He calls various words "Type", all selected words "Tokens", the ratio of various words to all words "Type-Token ratio" [diversity ratio] and abbreviated as "TTR" (Anari and Omidvar, 2012: 44). In this section, the number of different words is compared to the total number of words.

$$\frac{\text{Type}}{\text{Tokens}} = \text{Type - Token ratio}$$

From a total of three thousand words, from three narrative poems, Nizami, Jami, and Amirkhosro Dehlavi have 1021, 1080, and 1078 different words, respectively.

Table 2. The frequency of the number of different words.

Poet	The number of different words	TTR
Nizami	1021	34%
Jami	1080	36%
Amirkhosro Dehlavi	1078	35%

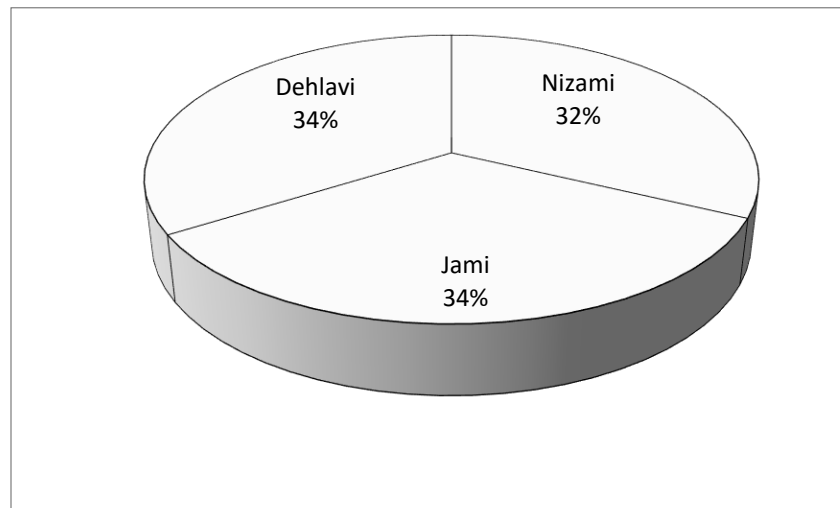


Chart 1. Chart of TTR.

3.3.2. Determination of the Average Value of Lexical Diversity Ratio

In this section, three following steps must be done:

"1. Dividing the text into parts of the same size; 2. Calculating different words to the total sum of words of the same component; 3. Obtaining the average value of the entire text with the help of the average value of each component, which is obtained by summing the average value of different components and dividing it by the number of constituent components of the text" (Bund Shahriari and Seyedrezaei, 2014: 51-52).

Three thousand words are divided into six sections that contain 500 words. Different words are counted in each section and divided by the number 6.

Table 3. The average diversity ratio in three narrative poems.

Poet	1	2	3	4	5	6	Average
Nizami	45.3	27.7	33.2	28.2	19.2	16.7	28.38
Jami	47.5	31.8	30.3	26.3	19.7	24.3	34.35
Amirkhosro Dehlavi	42.3	23.2	36	26.7	27.3	24.7	30

3.3.3. Chart of Stepwise Reduction of Lexical Diversity

Drawing a graph of the decreasing trend of lexical diversity helps us to show the amount of use of more different words by each poet. To draw this chart, several steps must be taken, which are described in the article by Anari and Omidvar (2012: 46):

- Dividing the text into parts of the same size in which three thousand words are divided into 6 parts.
- Calculating the diversity ratio in each component separately so that the lexical diversity of each part is determined and divided by the total number of vocabulary of this component.

To draw this chart, first, three thousand words are divided into 6 parts, and the variety of words in each part is counted and divided by the number of words in each part. For example:

Diversity ratio of the first component:

$$\frac{70}{500} = 0/14$$

Table 4. Stepwise reduction of lexical diversity.

Poet	1	2	3	4	5	6
Nizami	0.54	0.33	0.39	0.33	0.23	0.2
Jami	0.57	0.38	0.36	0.31	0.32	0.29
Amirkhosro Dehlavi	0.50	0.27	0.43	0.31	0.32	0.29

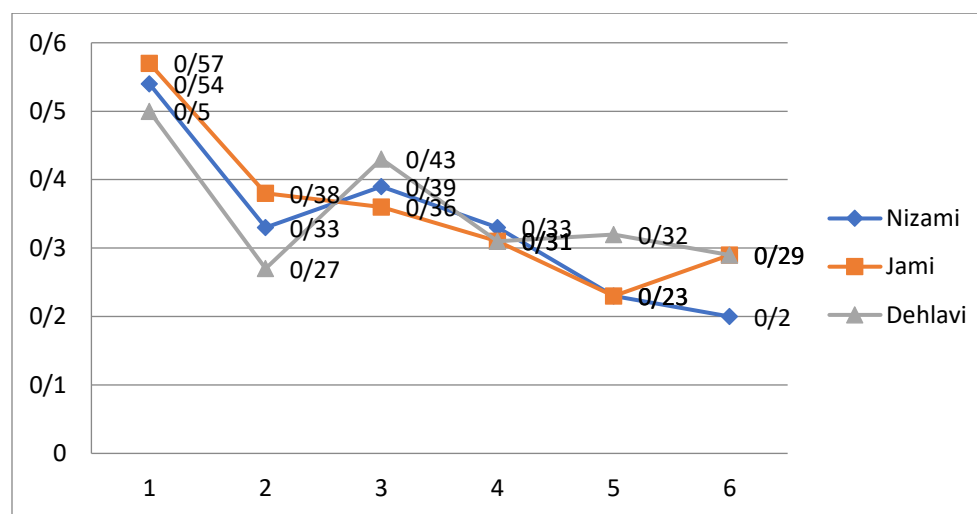


Chart 2. Chart of the TTR.

3.3.4. The Density Curve of Lexical Diversity Ratio

In this section, after dividing the words into equal parts, in each part, we will calculate the ratio of different words to the total number of words in the part.

In the first part, the number of different words is divided by the total number of words.

In the second part, the number of different words in this part is added to the number of different words in the first part and divided by the total number of words in the two parts.

In the third component, the number of different words of all three components is added together and divided by the total number of words of the three components. This process continues until all parts are completed so that the density ratio at the end of each component is determined (ibid: 48-49).

For example:

Diversity ratio in the first component: $\frac{60}{100} = 0/6$

Diversity ratio up to the end of the second component: $\frac{60+40}{200} = 0/4$

Diversity ratio up to the end of the third component: $\frac{60+40+30}{300} = 0/43$

Table 5. Stepwise reduction of lexical diversity.

Poet	1	2	3	4	5	6
Nizami	0.54	0.43	0.42	0.40	0.36	0.34
Jami	0.57	0.47	0.43	0.40	0.37	0.36
Amirkhosro Dehlavi	0.50	0.39	0.40	0.38	0.37	0.35

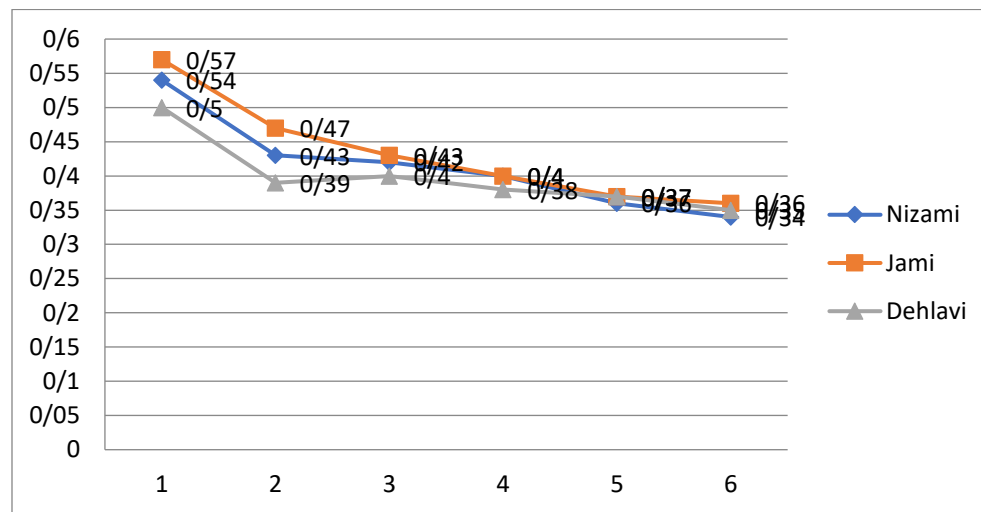


Chart 3. Chart of the TTR.

4. Comparison and Analysis of Results

The analysis of lexical diversity in the system of "Layla and Majnun" by Nizami, Jami, and Amirkhosro Dehlavi showed that Jami used more different words in his poems and this can be seen in the TTR table. Following Jami, most of the use of different words belongs to Amirkhosro Dehlavi and then Nizami. The statistical difference between different words in Jami's and Amirkhosro Dehlavi's poems is very close in terms of number, but they are slightly different in terms of the type of words.

Jami used a lot of compound adjectives in his verses and more diversity in Jami's vocabulary is due to his use of different compounds. These adjectives are often of noun types with a present participle, such as "creator", "thoughtful", "enlightening", and "preface writer".

Jami's descriptive compounds are often original and the poet has added a new word to his vocabulary to convey his purpose, such as "decided", "problem solver", "lucky", and "loyal".

Unlike descriptive compounds that are seen in many verses, Jami has used more simple verbs than compound verbs. In contrast, Amirkhosro Dehlavi has used simple and single-part words, but with more diversity than compound words, which indicates Jami's greater mastery in the field of word formation.

Most of the words used by Nizami are simple and he has used much less compound words than the other two poets. However, the important point is that when Nizami uses compound words, he creates new and innovative words and places them in his poetry, such as “praiser”, “secluded”, “opinionated”, “deaf”, and “village”.

The average value of lexical diversity shown in the corresponding table indicates that Jami with an average of 34.35% compared to Nizami with 28.38% and Amirkhosro Dehlavi with 30% has the highest amount of lexical diversity in six parts. This table shows that even though all three poets had a high lexical diversity in the first parts of their poems, when they approached the middle and end of each part, they used more repeated words. In the meantime, two poets at the beginning of their poems had lexical diversities of 45.3%, 27.7%, 33.2%, 28.2% (Nizami) and 47.5%, 31.8%, 30.3%, 36.3% (Jami), but, in the fifth and sixth parts, there is a significant drop in the number of words, which reduces their average percentage; But in the meantime, Amirkhosro Dehlavi has used a linear trend in the six investigated parts, so, except for the first part with 42.3% diversity, in the rest of the parts, the percentages are close to each other. This can be seen graphically in the charts of the stepwise reduction of words related to each poet.

In the charts and tables of the density ratio of lexical diversity, it can be seen that all three poets have vocabulary density close to the same so in the first part, all three poets have a ratio of close to 0.5 and are in the same line and this density can also be seen in the third, fifth, and sixth parts. Of course, the slight difference in these parts can be more related to the poetic style and the type of expression of the poems by each poet.

Due to his extensive knowledge of vocabulary, Nizami has used difficult and old words that are less noticed by other poets, such as “Voshaq”, “Aflas”, “Mosabat”, and “Khariteh”. Jami uses simple and comprehensible words for the general public, and primitive and technical words are less common in his poems. This trend is more visible in the poems of Amirkhosro Dehlavi, and his use of simple and single-part words is more than the other two poets.

In Nizami's poems, we can see his frequent and close use of words of the same root to create a musical song in the poem, such as “Shabrang, Shabahang”, “Meraaj, Meraj”, and “Bi parde, Parde shenas, Parde, Pardesazi, Parde daridegan” which all appear in three separate verses. The use of words with the same root or the repetition of a word in one or two verses in a row can also be seen in Jami's poems, e.g. “Maghsad, Maghsood”, “Naghshband, Naghsh”, and “Shekar amiz, Shekar riz”. However, in the poems of Amirkhosro Dehlavi, this type of use of cognate words is much less, so it can be considered as one of the characteristics that are the reason for the superiority of Jami and Nizami poems in poetic style over Amirkhosro Dehlavi.

The number of semi-auxiliary verbs in Nizami's poem is small compared to simple and compound verbs. Meanwhile, Jami and Amirkhosro Dehlavi have used semi-auxiliary verbs in a more limited way than Nizami.

5. Conclusion

- The numbers and statistics obtained in the process of this research are consistent, and this shows that the lexical circle of the three poets is roughly the same.
- The examination of nine thousand words from the three narrative poems of "Layla and Majnun" by Persian literature poets, showed that in the use of lexical circle, Jami has the highest frequency of words and the remarkable point is that the poem has less lexical circle than the poems of the two other poets but, Nizami has used numerous combinations and word constructions that are often unique to him, more than the other two poets, and this is one of the factors of the superiority of Nizami's "Layla and Majnun" narrative poem over the other two poems.
- The popularity of Nizami's "Layla and Majnun" narrative poem, compared to the other two poems, has other factors, among which we can point out how the words are placed together, which is not within the scope of this research. It is worth mentioning that Nizami uses different words to make sentences that have more linguistic features and the imagery he creates with the help of these words plays an important role in the acceptance of his poems among the people. This can be observed to a lesser extent in Jami's poems and to a much lesser extent in the poems of Amirkhosro Dehlavi.
- In the meantime, it is worth noting that although the statistical data and lexical diversity studies show the extent of the Persian vocabulary used by each poet, they do not reflect the superiority of one poet over another. For this purpose, there is a need for consistent research in the fields of literary industries, grammatical construction, illustration, etc.
- These results show that Nizami's poetic style, despite his little use of different words, has unique characteristics compared to the other two poets, which makes his style separate and unique from the two mentioned poets.

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Contrastive Analysis of Surah Al-Fatiha and Its English Translations As a Semantic Corpus-Based-Case Study

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ABSTRACT

The paper investigated Surah Al-Fatiha and its seven English translations as a corpus-based case study.

The researcher analyzed the Arabic Verses and their authentic English translations from seven well-known scholars, including Emily Assami et al. (Sahih International), Pickthall, Yusuf Ali, Shakir, Muhammad Sarwar, Mohsin Khan, and Arberry. All Parts of Speeches in two languages were identified and sorted according to the order of the Surah Al-Fatiha verses. Common words were selected in all translations of each verse of the Qur'an.

Keywords: Quran, Translation, Corpus Study, Semantics

1. INTRODUCTION

The Arabic language of the Qur'an is an integral aspect of this revealed Book [1]. The holy book of 1.6 billion Muslims, the Quran, has been translated into more than 100 languages. The earliest Persian translation appeared in the 7th century, the Latin translation in 1143, and the English translation in 1649. There have been numerous translations in each language: English translations by George Sale in 1734, Richard Bell in 1937, and Arthur John Arberry in 1955. Orientalists, non-Arabs, and Arab Muslims translated the Quran.

Consequently, English translations vary in style and accuracy. Some translators favored archaic English words and constructions; some used simple modern English; others added commentary. Some translated the meaning of the verses; others gave a word-for-word translation. There are occasional misinterpretations, mistranslations, or even distortions. The Translation of the Quran has always been problematic, as the Quran possesses both an exoteric and an esoteric meaning. The Quran uses rhymed Prose, and the Quranic message is conveyed with various literary structures and devices. In addition, a Quranic word may have a range of versatile and plausible meanings, making an accurate translation even more difficult. To reduce misinterpretations, mistranslations, and distortions of meaning, Islamic organizations such as Al-Azhar, and Quran scholars have set guidelines and policies for selecting Quran translators, evaluating, approving, and publishing those translations [2].

1.1 About the Holy Quran

The Quran is the holy book of 1.6 billion Muslims, living in almost all countries and speaking many languages. Basic beliefs of Islam include the existence of Allah and the Day of Judgment; ethical and legal issues; general rules and guidelines regarding right and wrong; narratives of the early prophets and historical events that took place during the Prophet's times; in addition to verses referring to natural phenomena. The Quranic message is conveyed through various literary styles and devices. The Surah and verses utilize phonetic and thematic structures that assist the readers in recalling the message of the Quranic discourse. The Holy Quran uses "rhyming prose". Rhyme changes from one set of verses to another, marking a change in the topic of the verses. The Quranic discourse is characterized by surface meaning and an underlying meaning, i.e., an exoteric and an esoteric meaning [2]. The holy book consists of 114 chapters, 6236 verses, 157935 words, and 668684 letters. [3].

1.2 The Holy Quran and Its English Translations

According to Professor Reima Al-Jarf, historically, the translation of the meanings of the Holy Quran went through 5 Stages:

Stage 1: The Quran was translated from Arabic into Persian.

Stage 2: The Quran was translated from Arabic into Latin. Stage 3: The Quran was translated from Latin into other European languages.

Stage 4: The Quran was directly translated from Arabic into European languages by non-Muslim Orientalists.

Stage 5: The Quran was translated from Arabic into European languages by Muslims

She stated that English translations of the Holy Quran vary in style and accuracy. Some translators of the Quran preferred using archaic English words and structures. For example, Abdullah Yusuf Ali and Muhammad Marmaduke Pickthall used "ye" (plural you) and "thou" (singular you) instead of modern "you". Some translators used simple modern English; some added commentary; some translated the meanings of the verses; others gave a word-for-word translation [2].

1.3The Quality of Translations of the Holy Book

English translations of the Quran, in particular, vary in style and accuracy of meaning. Translation of the Quran from Arabic has always been challenging for translators, as the Quran possesses both an exoteric and an esoteric meaning. The Quranic message is conveyed through various literary styles and devices. There are occasional misinterpretations, mistranslations and even distortions in the translation of the Quranic text from Arabic [2]. The Language Research Group at the University of Leeds has chosen 7 authentic translations, and they put all the translations and all Quran verse morphology and syntax on a webpage to be used by all researchers around the world.

2.About the Surah Al-Fatiha

Surah Al-Fatiha is the first surah in the Quran, and it is the most frequently recited surah in prayer. It is an essential pillar of the prayer, and the prayer is not valid without it, whether the worshiper is a follower or an imam, and whether the prayer is performed aloud or silently [4]. It consists of 7 verses, 29 words, and 143 letters.

3.The Aim of the Study

This study aims to compare and contrast 7 authentic English translations of Surah Al-Fatiha based on semantics to find the most common translation.

3.1.Methodology

The current research is a descriptive study based on two corpora of Quran verses and their English translations. The researcher investigates the Quran verses and their English translations to find the most common translation for Surah Al-Fatiha in the holy Quran based on Semantics.

3.1.1.Materials and Procedures

The researcher used online materials that are available at the Language Research Group at the University of Leeds website[5]. All verses in The Holy Quran have been shown as Arabic grammar, syntax and morphology for each word in the Holy Quran. As it is shown in Figure 1, syntax, morphology and the translation of each word are given, and that data is being used by all members to conduct research on the Holy Quran Corpus. Moreover, seven

authentic English translations are available too. Figure2. The researcher collected different translations for each surah of the Qur'an in a special table. Table 1 shows gathered translations and their equivalent Quranic verse.

Chapter (1) sūrat l-fāṭilah (The Opening)		
Translation	Arabic word	Syntax and morphology
(1:1:1) bis'mi In (the) name	بِسْمِ N P	P – prefixed preposition <i>bi</i> N – genitive masculine noun جار ومجرور
(1:1:2) l-lahi (of) Allah,	اللّٰه PN	PN – genitive proper noun → Allah لفظ الجلالة مجرور
(1:1:3) l-rahmāni the Most Gracious,	الرَّحْمٰنِ ADJ	ADJ – genitive masculine singular adjective صفة مجرورة
(1:1:4) l-rahīmī the Most Merciful.	الرَّحِیْمِ ADJ	ADJ – genitive masculine singular adjective صفة مجرورة

Fig. 1. Language Research Group at the University of Leeds Online Corpus
Data Including Translation, Arabic Word, Syntax, and Morphology[5]

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِیْمِ

Sahih International: In the name of Allah , the Entirely Merciful, the Especially Merciful.

Pickthall: In the name of Allah, the Beneficent, the Merciful.

Yusuf Ali: In the name of Allah, Most Gracious, Most Merciful.

Shakir: In the name of Allah, the Beneficent, the Merciful.

Muhammad Sarwar: In the Name of Allah, the Beneficent, the Merciful

Mohsin Khan: In the Name of Allah, the Most Beneficent, the Most Merciful.

Arberry: In the Name of God, the Merciful, the Compassionate

Quran Recitation by Saad Al-Ghamadi

Verse 1 | 2 | 3 | 4 | 5 | 6 | 7 >

Fig.2. Seven Different English Translations for Surah Al-Fatiha[5]

Table 1. The different translations for Quranic verse ”مَالِكِ يَوْمِ الدِّينِ”

Translator	Translation
Emily Assami(Sahih International)	Sovereign of the Day of Recompense
Pickthall	Master of the Day of Judgment

Yusuf Ali	Master of the Day of Judgment
Shakir	Master of the Day of Judgment
Muhammad Sarwar	and Master of the Day of Judgment
Arberry	The Master of the Day of Doom
Mohsin Khan	The Only Owner (and the Only Ruling Judge) of the Day of Recompense (i.e. the Day of Resurrection

4.Results

Verse1:

For “بسم” all the translators chose” In the name of” whereas for the word “الله” six of them chose “Allah” except for Arberry who picked the word “God”. For “الرحمن” four of them chose “The Beneficent,” Emily Assami chose” The Entirely Merciful”, Yusuf Ali chose “Most Gracious,” and Arberry picked “The Merciful”. For “الرحيم” six of them except for Arberry chose “the Merciful”, he picked “The Compassionate”. So the most common translation can be:

” In the Name of Allah, The Beneficent, The Merciful”

Verse2:

For “الحمد لله”, Picktall and Yusif Ali chose “Praise be to Allah”, Emily Assami chose” Praise is to Allah”, Shakir chose” All praise is due to Allah”, Muhammad Sarwar chose” All praise belongs to God”, Mohsin Khan’s words were “All the Praises and Thanks be to Allah “, and Arberry differently chose “Praise belongs to God”. It seems that there are many differences in the translation of this part of the verse, however, they all agreed on the word “Praise”. For “رب العالمين” six of them used “Lord” or “The Lord” as “رب”, but Yusif Ali Chose different words as” the Cherisher and Sustainer of the worlds” for “رب العالمين”. For “العالمين” four of them chose “the worlds” including Yusif Ali. Muhammad Sarwar and Arberry picked” The Universe” and “All Beings,” respectively; however, Mohsin Khan’s translation was totally different from the all of them, as it was “The Lord of the 'Alamin (Mankind, Jinns and All That Exists).So, the most agreed translation among them is:” Praise be to Allah Lord of the Worlds”.

Verse3:

Like verse one, for” الرحمن” four of them chose “The Beneficent”, Emily Assami chose” The Entirely Merciful”, Yusuf Ali chose “Most Gracious”, and Arberry picked “The Merciful”. For “الرحيم” six of them except for Arberry chose “the Merciful”, he picked “The Compassionate”. So the most common translation can be:

"The Beneficent, The Merciful"

Verse4:

For” مَالِك”, five of them chose “Master”, whereas, Emily Assami chose “Sovereign “and Mohsin Khan chose “The Only Owner (and The Only Ruling Judge), it should be mentioned that Arberry was among five translators who chose “Master”. For” يَوْمَ الدِّينِ” four of them chose” the Day of Judgment” while Emily Assami chose “the Day of Recompense”, Mohsin Khan chose “the Day of Recompense (i.e. the Day of Resurrection)”, and Arberry chose “the Day of Doom”. So the most agreed translation can be:” Master of the Day of Judgment”.

Verse5:

For "وَإِيَّاكَ" four of them used "Thee" whereas Emily Assami chose "It is you", Muhammad Sarwar and Mohsin Khan chose "(Lord) You Alone" and "You (Alone)" respectively. Among those who used "Thee", Pickthall used "Thee(Alone)". For "نَعْبُدُ", five of them including Emily Assami, Pickthall, Yusuf Ali, Muhammad Sarwar, and Mohsin Khan used "We Worship" although, Yusuf Ali and Muhammad Sarwar used "do" their translations too.

For "وَإِيَّاكَ نَسْتَعِينُ" four of them used word "Help" in their translations, except for Yusuf Ali who chose "Aid", Muhammad Sarwar who picked "Assistance", and Arberry who picked "Succor". For "وَإِيَّاكَ نَسْتَعِينُ" almost all of them used different translations except for word "Help". Emily Assami, Pickthall, and Mohsin Khan used "we ask for help" in their translations, so it can be said that the most common agreed translation for the verse 6 is:

"Thee do we worship and You we ask for help".

Verse 6:

For "اهْدِنَا", Emily Assami, Muhammad Sarwar, Mohsin Khan, and Arberry used "Guide us" while Pickthall and Yusuf Ali used "Show us", and Shakir used "Keep us". For "الصِّرَاطَ" all of them used "Path" except for Yusuf Ali and Mohsin Khan who chose "Way". For "الْمُسْتَقِيمَ" all of them used "Straight" except for Shakir and Muhammad Sarwar who used "right". So the most agreed translation can be:

"Guide us to the straight path"

Verse7:

This is the longest verse in the Surah. For "صِرَاطَ" all of them used "The Path" except for Yusuf Ali and Mohsin Khan who used "The Way". For "الَّذِينَ" all of them used "Those" and "Whom" in their translations. For "أَنْعَمْتَ عَلَيْهِمْ" Four of them including Emily Assami, Yusuf Ali, Shakir, and Mohsin Khan used "Bestowed" while Pickthall and Arberry used "Hast", and Muhammad Sarwar used "Granted" moreover, Emily Assami, Pickthall and Shakir used "Favor(s)" or "Favored" while Yusuf Ali and Mohsin Khan used "Grace". Muhammad Sarwar and Arberry used "Blessing" and "Bless" respectively.

For "غَيْرِ الْمَغْضُوبِ عَلَيْهِمْ", Emily Assami, Pickthall, Muhammad Sarwar, and Mohsin Khan used "Anger" in their translations while Yusuf Ali, Shakir and Arberry used "Wrath" and "Wrathful". For "وَلَا الضَّالِّينَ" all of them used "Astray". The word is the only word that all of them were agreed to use it in the translations of verse 7. It should be added that all of them used "to be astray" or "to go astray" So the most common translation can be:

"The path of those upon whom You have bestowed favor, not of those who have evoked [Your] anger or of those who are astray".

5.Limitations of the Study

This study has its limitations, like all case studies. The first limitation is that this study was conducted on only one surah of the Quran. The second limitation is that this study has selected only 7 authentic translations, while the number of translations of the Qur'an in English is much more. The third limitation is that this study only considered meaning and did not consider other categories like syntax, morphology etc.

6.Conclusions

Finding the most common translation for the Surah Al-Fatiha is possible, although determining a standard for the Qur'anic translation in general and the Fatiha surah in particular requires extensive linguistic studies in both Arabic and English languages.

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The Other in Toni Morrison's *A Mercy*: A Zizekian Reading

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ABSTRACT

This article is an attempt to investigate how concepts of lack, Other, objet a and subjectivity formation are reflected in Toni Morrison's *A Mercy* (2008). A study of the impactful locality of the Other in Morrison's *A Mercy*, in the lens of Zizek, depicts the laws that the black characters have to observe to be identified—not defined—as subjects by the Other. The crack between the signifier and the signified causes a lack which sets the desire for the objet a in motion and to compensate for the fundamental lack, the Other provides a symbolic signifying chain of signs and codes for the subject to gain symbolic identity. Morrison portrays Florens's lack as it deals with separation and alienation with her (m)other which leads her to a search in the symbolic ideal world of the Other to regain the lost object and fulfill the lack in order to gain access to her symbolic identity. The article aims to illustrate the separated and alienated subject's search for the lost object and its journey in the symbolic order through which this search remains unfulfilled and the subject's unconscious search will be continued to an unknown and unsymbolized realm, the real. The study looks into the maternal role in the formation of the lack and the unconscious desire to compensate for the lost object in the symbolic Other in Morrison's character, Florens, in light of Slavoj Zizek's conceptualization of subjectivity.

Keywords: Toni Morrison. Slavoj Zizek. Other. Subjectivity. Objet a.

INTRODUCTION

A complex network of relations shapes subjectivity and a subject's interaction with its external world will form it. In *The Sublime Object of Ideology* (2008) Zizek argues that “only by being reflected in another man— that is, in so far as this other man offers it an image of its unity— can the ego arrive at its self-identity; identity and alienation are thus strictly correlative” [1]. First, there is an illusory sense of unity and wholeness; then, a recognition of fragmentation makes the subject to find the lost part in the external world and be whole and united again. The subject realizes that it is fragmented and there is a gap between it and its other part which exist in the external world. “What Lacan calls the ‘small other’” is “the idealized mirror-image of my ego” and “the point of my symbolic identification” is “the point in the big Other from which I observe (and judge) myself” [2]. The gap between the fragmented subject and the divided image of the other leads to a desire for the lost object and causes the subject's journey in the external symbolic world of the Other. Since the core of the unconscious is lack and this lack is caused through the vision of experiencing separation and alienation from an external object, the fragmented subject searches in the external world to compensate for its desire for the lost object to fulfill the lack. The Other which provides a signifying chain of signs for the subject to search in it can be determined as Father or Language or Law or even the reality of death [3]. While the subject attempts to fulfill the lack, it has to adapt its desire with the Other's desire through the signifying chain of signs and rules.

Theoretical Underpinning

The subject finds its subjectivity through matching its desire with the predefined desire of the symbolic Other. The vision of lost wholeness leads the desirous subject to the realm of the Other, symbolic order, to fulfill the lack. The subject searches for the lost object to subjectify its subjectivity which is an unconscious attempt and since the subject keeps searching in the symbolic chain of signs of the Other, it will be identified as a subject. “For late Lacan, the object is precisely that which is ‘in the subject more than the subject itself’, that which I fantasize that the Other (fascinated by me) sees in me” [4]. Žižek mentions that the internal sense of lack creates the desire which is not internal but external: “the original question of desire is not directly ‘What do I want?’, but ‘What do others want from me? What do they see in me? What am I to others?’” [5]. Since the desire is defined by the Other, Žižek admits that fantasy is “an attempt to provide an answer to ‘what does society want from me?’” [6]. In other words, the concept of subjectivity relates to the other and the subject will find even its fantasy to fulfill the visionary lack through the interaction with the Other in the external world. The subject intends to be identified by the Other through matching itself with the signifying chain of signs and laws of the symbolic Other. According to Žižek “ideological illusion lies in the ‘knowing’. It is a matter of a discordance between what people are effectively doing and what they think they are doing” [7]. The subject attempts “to form an identity” that “would satisfy” the Other’s desire and make it “the object” of its “desire” [8]. The subject has to match itself with the systematic symbolic signifiers and signified to be recognized as a subject by this symbolic ideological Other and “fantasy mediates between the formal symbolic structure and the positivity of the objects we encounter in reality” [9]. The positivity of the objects concerns the phantasmic formation of the Other’s desire which is an answer to the Other’s desire with which the subject has to match its desire.

Žižek mentions that in symbolic reality, the rules and laws that the Other provides for the subject, there is an empty gesture and that “involves a paradoxical point at which the subject is ordered to embrace freely, as the result of his choice, what is anyway imposed on him” [10]. Žižek also argues that “the gesture which constitutes the subject is the empty gesture of a forced choice: reality is “subjectivized” when the subject posits as his free choice what is forced upon him, i.e., what he encounters as given, positive reality” [11]. The subject is identified as a subject since it remains in the symbolic chain of the Other to fulfill the unconscious journey of finally finding the lost object; the symbolic gesture produces an ideological system of signs that provides “possibilities of choices which must never actually take place, since their occurrence would cause the system to disintegrate, and the function of the unwritten rules is precisely to prevent the actualization of these choices formally allowed by the system” [12]. Moreover, the Other suggests the signifying chain for the subject to remain searching for the Other’s desire and fulfill the gap/lack and be the unconscious subject by matching itself with it. The symbolic Other supports the unconscious desire for the loss and the unconscious subject is identified as a subject while it remains in the symbolic chain of signs and laws of the Other.

Fantasy allows the subject to keep searching as a desirous subject to form its symbolic reality:

Fantasy does not mean that when I desire a strawberry cake and cannot get it in reality, I fantasize about eating it; the problem is, rather: how do I know that I desire a strawberry cake in the first place? This is what fantasy tells me. [13]

The ideological Other provides the fantasy of fulfilment and it seems that the desirous subject attempts to grasp the signs and laws to compensate the lack and experience wholeness again. Since the loss is illusory because the separated and alienated external part did not exist at first and was imaginary, the lost object cannot be compensated and the subject’s search is to no avail but this search for the Other’s desire makes it the unconscious subject of the symbolic world. The desire of fulfilment cannot be fulfilled and the ideology provides another phantasmic object for the subject in order to keep searching. The subject receives the suggested object cause of desire and quests the ideologically produced signifying chain although it cannot match its desire for the lost object in the Other’s desire:

What we have here is symbolic exchange at its purest: a gesture made to be rejected; the point, the ‘magic’ of symbolic exchange, is that although in the end we are back where we were at the beginning, the overall result of the operation is not zero but a distinct gain for both parties, the pact of solidarity. [14]

The Other offers signs and rules which cannot be matched with the subject's desire so there is a loss that will remain and the search for the object cause of desire, objet a, keeps going somewhere beyond appearance of the symbolic order. "The big Other (the symbolic order) collapses into the small other, objet petit a, the fantasy object. The extraction of objet a from the field of reality confers on this field its consistency" [15]. In other words, the Other provides paradoxical parties which leads the subject to what is beyond the laws and while the subject sees that phantasmic answer for its loss, it is aware that being matched with this phantasmic object is impossible because as soon as the subject stops its quest in the symbolic Other, it won't be identified as the symbolic subject. Zizek refers to the notion of inherent transgression to states that the Other provides rules and laws and at the same time phantasmic imagination "you know that these fantasies are not 'for serious' that they don't count in the eyes of the big Other" [16]. Thus, as the subject is searching in the symbolic chain of signs and laws of the Other for the lost object of desire, it faces phantasmic imaginary structure that allows him observe an answer which is beyond the predefined rules and laws but to remain the subject of the symbolic external world it has to stay in the world of the Other.

This study aims to investigate Toni Morrison's *A Mercy* (2008) through Zizek's theory of subjectivity and how this notion concerns the main character, Florens, while she is wandering in the symbolic external world, looking for her lost object of desire unconsciously. Morrison begins her novel with Florens's last memory of her mother as she is obliged to leave her and her brother to live with a new master, Sir Jacob Vaark, the owner of a farm and an estate, and four women by whose help he runs the estate, are the five characters of utterly distinguished origins and socio-cultural conventions. As a black female figure, Florens, confronts conflicts and she has to overcome them through finding answers by following the orders and rules of the estate and society in a vast scope. She gets along with Sir's death and the Mistress's illness and begins a journey to find the way to save the Mistress since her identity is defined by the existence of the estate. She leaves the estate to bring help; the blacksmith is the only one who can lend a hand to their misery and Morrison depicts that Florens is also in love with the blacksmith and this promotes her to the bravery to leave the estate and begin a new journey full of unknown and undetermined happenings. Since the whole narration is a complaint to the disturbing conflicts and the black marginal female subject who has experienced fragmentation, the novel contains the potential to be studied in light of Zizek's ideas related to subjectivity.

Discussion

A Mercy opens with: "Don't be afraid" [17] and directs the reader to the narrator's mother's role who was a black slave and ignored her daughter's desire for shoes; "The beginning begins with the shoes. When a child I am never able to abide being barefoot and always beg for shoes, anybody's shoes, even on the hottest days" [18]. Wang Lei argues that

This work uses the term maternal silence to represent both the physical absence of the black mother due to the systematic breaking up of slave families under slavery and black mothers' failure to offer their children life-affirming functions due to the psychic scars inflicted on them by the chattel system. [19]

Florens who is also a slave and has inherited this job from her mother narrates: "my mother, a minha mãe, is frowning, is angry at what she says are my prettify ways. Only bad women wear high heels. I am dangerous, she says" [20]. The story illustrates Florens's experience of the lack and the beginning of the unconscious quest from the imaginary realm of the other to the symbolic realm of the Other in which she has to be identified as a subject. The fragmented subject who is alienated and separated from the other and has lost the sense of unity and wholeness begins a journey to fulfill the lack: "My head is light with the confusion of two things, hunger for you and scare if I am lost" and she admits that "nothing frights me more than this errand and nothing is more temptation. From the day you disappear I dream and plot. To learn where you are and how to be there" [21]. It seems that Florens who is separated from her mother and is alienated with her begins a journey to the symbolic order:

I want to run across the trail through the beech and white pine but I am asking myself which way? Who will tell me? Who lives in the wilderness between this farm and you and will they help me or harm me? What about the boneless bears in the valley? Remember? [22]

Florens's mother asks Jacob Vaark to take Florens from the house that she works in to save her: "I heard their voices and gathered you and your brother to stand in their eyes. One chance, I thought. There is no protection but there is difference" [23]. Morrison describes Florens's separation from her mother as a request that is emphasized by her mother: "take the girl, she says, my daughter, she says. Me. Me" [24]. She also bans Florens's interest in shoes and prevents her from her desire for shoes. Since mother is regarded as the first other, Florens's mother is described fully as the other by whom she experiences alienation and also separation before leaving her with Jacob Vaark. The first pages of the novel can be considered as an illustration of the position of the other, the sense of lack which causes the unconscious subject's journey to the symbolic order.

Since the symbolic order provides the phantasmic object of desire through offering the Other's signifying chain of signs and laws, Florens's journey to Jacob Vaark's estate provides new condition with its predefined laws and rules which she has to adapt her with in order to be identified as a member of that house:

At first when I am brought here I don't talk any word. All of what I hear is different from what words mean to a minha mãe and me. Lina's words say nothing I know. Nor Mistress's. Slowly a little talk is in my mouth and not on stone. [25]

The fragmented subject has to match its desire with the desire of the Other in order to fulfill the gap that exists between it and the external Other. Florens's sense of not being one with the mother as the first Other seems to lead her to a journey of finding the lost other in order to adapt herself with the rules, laws, codes and signifiers of the signifying chain of the symbolic Other. The Other in this novel appears in Sir, Senhor, the predefined rules and laws by the white society for black people, religion, culture, and every single existence that suggests a signifying system of signs and codes to the split subject(s) to be matched with. Florens deals with a lost object from the opening parts of the story and is described as one who is lost and is in search of someone she loves greatly: "A frightened, longnecked child who did not speak for weeks but when she did her light, singsong voice was lovely to hear" [26]. In such a society, a slave's lifestyle is predetermined and predominated, and slaves have no way except accepting the rules and matching themselves with those laws in order to be members of that society.

Ehsan Azari acknowledges that "the imaginary juncture" [27] by which the subject experiences alienation and separation through mirror phase is referred to as the object in desire and the object which is relevant to the symbolic Other that offers signifying chain of signs and laws to the subject in order to adapt its desire with it to regain wholeness is called the object of desire. According to Azari, the object in desire creates the fundamental lack that leads the subject to the symbolic journey in the Other and "this object returns in the symbolic as an object a" [28]. Morrison illustrates that the experience of separation and alienation is caused by Florens's mother as she asks Vaark to take her and as a fragmented subject, Florence has to begin her journey in the symbolic Other. The chain of signs that the Other offers to the subject cannot fulfill the desire for the object cause of desire, objet a, and leads the subject to the phantasmic object that is abandoned in appearance but the paradoxical nature of the Other provides this position. Since Vaark is dead, to save the Mistress and the estate, Florens must go after the blacksmith. Morrison shows that Florens realizes that to be identified as a subject she has to positive the symbolic Other, the estate. She knows that loving the blacksmith is prohibited but she has to find him. "The institution exists only when people believe in it, or, rather, act as if they believe in it" [29]. Žižek argues that the Other provides ideology to save itself and through its paradoxical function the subject twists between the appearance of the order and phantasmic object, to remain the subject. Symbolically, Florens finds the blacksmith to compensate for her sense of loss:

Standing there between the beckoning wall of perfume and the stag I wonder what else the world may show me. It is as though I am loose to do what I choose, the stag, the wall of flowers. I am a little scare of this looseness. Is that how free feels? I don't like it. I don't want to be free of you because I am live only with you. When I choose and say good morning, the stag bounds away. [30]

Love of the blacksmith leads Florens to a quest to find him and fulfill her lost imaginary sense of being one and united with the lost one, the thing, objet petit a, but as long as she loves him, she admits that this is not lawful:

I am not wondering this. Not then, not ever. I know you cannot steal me nor wedding me. Neither one is lawful. What I know is that I wilt when you go and am straight when Mistress sends me to you. Being on an errand is not running away. [31]

Morrison depicts Florens's journey to the woods. Florens leaves the estate to start a different journey to a place that is far away to find the blacksmith and through her search she turns into the woods, where no one has any access to locate her. There are parts of narration that illustrate Lina's anxiety toward Florens's loss. She is nowhere to be found. After leaving the estate to take the blacksmith, Florens abandons fellow travelers and when Lina asks them about Florens, they cannot give an accurate answer:

Lina went on, "There was a maid with you. I put her aboard." "There was," said the man. "What happened to her?" The women shook their heads and shrugged. "She left the wagon," said one. Lina placed her hand beneath her throat. "She got off? Why?" "Couldn't say. She went into the woods I believe." "By herself?" "We offered her to join us. She chose not to. Seemed in a hurry." "Where? Where did she get off?" "Same as us. The tavern." "I see," said Lina. She didn't, but thought it best not to press. [32]

Florens cannot be lost in the woods because she has the letter with her in which she is identified as a subject to the estate and has to follow the predefined path to find the blacksmith to save the Mistress and the estate:

Then he picks it up and reads aloud. The signatory of this letter, Mistress Rebekka Vaark of Milton vouches for the female person into whose hands it has been placed. She is owned by me and can be knowne by a burne mark in the palm of her left hand. Allow her the courtesie of safe passage and witherall she may need to complete her errand. Our life, my life, on this earthe depends on her speedy return. [33]

Even when she meets Daughter Jane and realizes that she is the demon, Florens does not leave her predefined law and asks her how can she find her way to the blacksmith:

Daughter Jane hands me the cloth of eggs. She explains how I am to go, where the trail will be that takes me to the post road that takes me to the hamlet where I hope you are. I say thank you and lift her hand to kiss it. She says no, I thank you. They look at you and forget about me. She kisses my forehead then watches as I step down into the stream's dry bed. I turn and look up at her. Are you a demon I ask her. Her wayward eye is steady. She smiles. Yes, she says. Oh, yes. Go now. [34]

In the defined paradoxical fantasy of fulfillment that is defined by the Other the subject stays and quests to match its desire with the symbolic chain of signs and rules that are offered by the Other and Morrison's novel portrays Florens's unconscious attempt to remain the subject of the Other, although she could get lost in the woods, be sacrificed and murdered as the demon—since her skin is black—by the widow Ealing and her companions or even stay with Daughter Jane.

Morrison portrays a subject of ideology as she follows the ideological paradoxes that are defined by the Other. Florens begins a quest to save the estate in appearance but what she is keen about is finding the phantasmic object cause of desire that is also defined by the Other and as long as she is following her mission, she is the subject of the Other:

a minion with no telltale signs but a darkness I am born with, outside, yes, but inside as well and the inside dark is small, feathered and toothy. Is that what my mother knows? Why she chooses me to live without? Not the outside dark we share, a minha mãe and me, but the inside one we don't. Is this dying mine alone? Is the clawing feathery thing the only life in me? You will tell me. You have the outside dark as well. And when I see you and fall into you I know I am live. Sudden it is not like before when I am always in fright. I am not afraid of anything now. The sun's going leaves darkness behind and the dark is me. Is we. Is my home. [35]

The ideological paradoxes that are defined by the Other save the Other to survive as the ruler of the external world and if it does not contain these paradoxes, Žižek, mentions that it will lose its essentiality and existence:

These thoughts are sad in me, so I make me think of you instead. How you say your work in the world is strong and beautiful. I think you are also. No holy spirits are my need. No communion or prayer. You are my protection. Only you. [36]

Morrison illustrates that Florens, as a desirous subject who left her mother to be identified as a member in Vaark's estate, finds the way to leave the appearance and twist to another ideologically production of the Other, love, which provides the ground to stay in the symbolic chain of the Other and save it. Florens meets the blacksmith but he refuses her love and rejects the existence of an emotional relation between them. The Other offers the symbolic objects to the desirous subject to compensate for its lack through matching its desire with the Other's desire and fulfill the wholeness but as the wholeness is an imaginary vision relevant to the realm of the (m)other, the subject's attempt is to no avail:

You are nothing but wilderness. No constraint. No mind. You shout the word—mind, mind, mind—over and over and then you laugh, saying as I live and breathe, a slave by choice. On my knees I reach for you. Crawl to you. You step back saying get away from me. I have shock. Are you meaning I am nothing to you? That I have no consequence in your world? My face absent in blue water you find only to crush it? Now I am living the dying inside. No. Not again. Not ever. Feathers lifting, I unfold. The claws scratch and scratch until the hammer is in my hand. [37]

Florens is shown as a fragmented subject who has found her wholeness in this love as it is offered to her, however, since the wholeness is not a symbolic reality but an imaginary vision, she cannot fulfill her desire for the lost object through symbolic objects of desires that the Other suggests:

I want you to go. Let me explain. No. Now. Why? Why? Because you are a slave. What? You heard me. Sir makes me that. I don't mean him. Then who? You. What is your meaning? I am a slave because Sir trades for me. No. You have become one. How? Your head is empty and your body is wild. I am adoring you. And a slave to that too. You alone own me. [38]

As discussed, the paradoxical appearance and phantasmic objects that are defined by the ideology function to make the subject, the subject of the Other. As the love object, the blacksmith, denies her love and she has no choice but to return to the structure of her symbolic reality where she is a slave in the estate. It seems that the whole journey that is offered to Florens is just an ideological production of the Other to keep the subject searching in the external symbolic world just to subjectify its subjectivity and as soon as this search is ceased the subject loses its symbolic identity so the Other provides phantasmic objects to hold it: "Before and after the blacksmith healed Mistress and the girl, Florens, was back where she belonged, a pall had descended" [39]. Mistress is saved after the blacksmith meets her and the circumstances of the estate back to normal.

The paradoxical position that the Other provides for the subject is considered as an ideology by Žižek that leads the subject to search for the answer to its sense of loss in the predefined signifying chain of signs and laws. By following the predefined symbolic chain of signs and laws, the subject gives meaning to the existence of the Other and the symbolic dominant and controlling ideology. In other words, the fragmented subject transfers to the realm of the symbolic through which it desires to regain the lost object and the symbolic Other offers the ideology and its signifying chain of laws to the subject to search in order to compensate for the sense of lack through matching its desire with the desire of the Other and experience the lost wholeness again. A Mercy is a portrayal of this subject-object relation through an ideology and fantasy offered by the symbolic Other. Morrison shows that the alienation and separation from the mother as the first other is mentioned through the eyes of Florens and how she faces the departure from her maternal circumstances and begins her quest in the external world and the suggested laws and rules by which she has to adapt herself with unconsciously. Then, Morrison shows the essentiality of leaving the estate in order to save it which is an attempt to save Florens's own subjectivity and as she leaves the estate, she has a letter that attaches her identity to the estate as a symbolic Other. The letter connects her identity with the estate and saves her subjectivity and symbolic life even outside of the Other. Considering the estate as the symbolic Other which admits Florens's identity seems to be relevant to the ideology and the paradoxical modes which provide the chance of leaving the estate,

the Other, while she knows that she must return to it. Florens leaves the estate to follow the ideologically produced chance of experiencing love to fulfill her sense of loss and bring help since the estate needs this journey to sustain the dominant and controlling external symbolic existence. Overall, the desirous black character who needs to find her subjectivity in the external white society has to start a journey from marginal maternal order to the central ideological symbolic signifying chain of the Other in order to subjectify its subjectivity through matching her desire for the lost object, objet a, with the Other's desire and by attempting so she will be saved and identified as a subject of the external symbolic society.

Conclusion

Considering *A Mercy* by Toni Morrison in light of Žižek's theory of fantasy provides a prolific setting to argue the relation between the subjectivity formation and the impactful role of the symbolic ideology. The paradoxical nature of symbolic ideology mediates between the symbolic order and the phantasmic structure and positivity of the objects that the subject faces through its unconscious journey to fulfilment. In *A Mercy*, Florens is portrayed as the desirous subject who follows her unconscious search to compensate for her sense of lack and as she leaves her maternal world and begins a quest in Vaark's estate, she confronts the paradoxical structure of the reality which is a mission to save the estate that leads her to the fantasy of love for the blacksmith. The concept of subjectivity formation which is relevant to the loss of the object cause of desire is investigated in this study through the notion of ideological Other which mentioned by Žižek to conceal the function of symbolic structure and certain phantasmic objects that provide a schema for the unconscious subject to form its subjectivity. Florens is observed as the marginal character who comes from a black mother to the symbolic world of white society and has to adapt her desire with the predefined laws and rules of them to be identified as a subject. This study illustrates the utilitarian situation that the ideological Other produces in the society and every marginal member can be identified as a subject of this structure by following its predefined symbolic chain of signs and laws through investigating Morrison's *A Mercy* in light of Žižek's relevant theories.

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Study of the relationship between critical self-criticism and social anxiety with fear of failure among girls (case study: students of the first middle years of the shahid Chozukulu high school in Pakdasht

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ABSTRACT

The study was conducted with the objective of studying the relationship between self criticism and social anxiety and timidity among the first female students at the Imam Chozukulu high school in Pakdasht, by means of a comparative survey of the whole of the first secondary school, of 650, out of which 241 were selected as statistical representatives. The data collected were using a questionnaire, whose contents were checked for their validity and validation by the Rigerson factor, and the statistics tested by SPSS26 and AMOS24.

Keywords: self criticism, social anxiety.fear of failure

1-INTRODUCTION

One of the most important issues and concerns of teenagers is establishing effective communication and social relations with others. Since one of the main foundations of mental health and psychological well-being is to have proper social relations, most likely, a deficiency in these relations will cause problems. Shyness is a common personality trait that many people have; It is especially seen in teenagers. Shyness is defined as stress, discomfort and fear of social situations, especially among unfamiliar people. Although shyness in itself is not harmful and can have benefits, but extreme and pathological shyness; It leaves negative and destructive effects on people's mental health.

The relationship between self-criticism, social anxiety and shyness among female students is an important issue for this research for several reasons; The first reason is that; Adolescence is a very sensitive period for the development of personal identity and social skills. Shy teenagers may face challenges in creating a positive self-perception and establishing healthy relationships with others (Pollak et al., 2021) [4].

Second, gender differences also play an important role in the expression and impact of shyness. Several studies have shown that girls are more shy than boys and shyness has more negative effects on girls' mental health and academic achievements (Wang et al., 2022) [5].

Third, understanding the relationship between self-criticism, social anxiety and shyness can help us identify the risk factors associated with shyness and create effective interventions for shy adolescents (Nyborg et al., 2022 [6]. In general, Examining the relationship between self-criticism, social anxiety and shyness among first-year high school girls is a valuable research topic that can help develop psychological knowledge and effective interventions. By doing this research, we can gain a deeper understanding Let's find out the factors and consequences of shyness and consider useful solutions to increase self-esteem, social skills and mental health of shy teenagers.

2.Theoretical foundations and research background

Discussion and study on the phenomenon of self-criticism goes back to Greek philosophers. Although experimental researches in the field of this concept and its relationship with psychopathology and psychotherapy have started since the seventies (Ahmadi and Rostamnejad, 1400) [7]. Self-criticism can be defined as a person's tendency to have high expectations of himself and He defined questioning his own performance (Ramroudi et al., 1401) [8]. Self-criticism

is a personality trait by which a person evaluates himself strongly. This trait brings negative consequences such as depression, stress, anxiety, disturbed interpersonal relationships, negative emotions and high levels of discomfort. (Basreh and Mami, 1402 ([9]) Self-criticism is one of the variables that is characterized by a feeling of extreme humiliation, guilt, worthlessness and a feeling of failure in accordance with the expected standards. When people commit a mistake or create a problem that is caused by not social approval or reaction, this means a threat to "self". Therefore, self-criticism can be seen as self-demanding attention to an intrusive error or mistake, along with a punitive reaction (Meng et al., 2021). 10].

Humans have been struggling with social anxiety since the beginning of creation. The term social anxiety is derived from a German word that means fear. Greek and Latin doctors and philosophers distinguished social anxiety from negative emotions and introduced it as a medical disorder (Lee et al., 2023). Social anxiety is an unpleasant and vague feeling of apprehension and fear, with an unknown origin A person shakes hands and causes uncertainty, helplessness and physiological arousal. Social anxiety is actually an internal state and a natural response of humans to stressful situations or psychological pressures (Lee et al., 2023). Children with social anxiety disorder are anxious in many social situations (such as school, teams, playdates, remedial classes, and even family gatherings). This phobia can negatively affect their academic performance, social relationships, self-confidence and other functional areas. Children with social anxiety disorder avoid participating in activities such as sports or other group activities with their peers due to fear of negative judgment or embarrassment (Benson, Nicholas and Tako, 2022) [11]. According to psychologists, shyness is considered as a defect and deficiency in social relations, which affects the individual-social functioning of individuals. Shyness is defined as discomfort and inhibition in the presence of others, which overlaps in many aspects with social anxiety or fear, inhibited behavior and social withdrawal (Salehi, 1402)[12].

Shy people experience anxiety in unfamiliar situations or when interacting with others, and their lives are severely affected and limited (Gang et al., 2021) [13].

Shyness, with important symptoms such as low facial expressions, avoiding physical contact, looking down, talking in a low voice, being passive and avoiding fearful situations, increased heart rate, dry mouth, tremors, Sweating, general weakness, confusion, fear of losing control, negative self-evaluation, negative thoughts about yourself and others, confusion, shame, low self-esteem, loneliness, sadness, discouragement, anxiety and it is depression Birang Alivandi, 1400 [14].

Various researches have been conducted in relation to self-criticism, social anxiety and shyness, some examples are mentioned below:

Moghadam et al.(1401)[15] conducted a research entitled "The relationship between hypocrisy and neuroticism with social anxiety: the mediating role of effortful control". The results showed that only the relationship between shyness with social anxiety and shyness with effortful control was significant (positive and negative, respectively). Effortful control does not mediate the effect of neuroticism on social anxiety and the effect of hypocrisy on social anxiety. Similarly, neuroticism has no effect on social anxiety. On the contrary, the whole model consisting of a combination of shyness, neuroticism and effortful control variables can explain social anxiety.

Hasanpour, Alizadeh Mousavi and Mohammadipour (1401) [16] conducted a study entitled "Investigation of the mediating role of self-criticism between emotional self-regulation and low self-esteem in adolescents, psychological studies of adolescents and young adults". The findings showed that the causal model of students' hypocrisy based on emotional self-regulation with the mediating role of self-criticism has a suitable fit. Also, emotional self-regulation has a direct effect on self-criticism, and emotional self-regulation has a direct effect on hypocrisy. Another is that self-criticism has a direct effect on hypocrisy, and self-criticism plays a mediating role between emotional self-regulation and hypocrisy. It can be concluded that self-criticism plays a mediating role between students' emotional self-regulation and shyness; Therefore, the planners of the educational system with the help of psychologists and school counselors can include the necessary measures in the curriculum in order to solve the low self-esteem of students.

Pourjafari and Karimi (1401) [17] conducted a study under the title of "relationship between shyness, social anxiety and tension symptoms with depression in undergraduate students of Payam Noor University, Haftgol". The results showed that there is a positive and significant relationship between depression, social anxiety and tension symptoms. Also, the results of the regression analysis showed that hypothermia, social anxiety and stress symptoms are significant predictors for depression and together they explain 28% of the variance of the criterion variable (depression).

Alizadeh (1400) [18] conducted a study entitled "The relationship between shyness and social anxiety of students using the mediating role of fear of failure and perceived stress". The findings of the research showed that students with high perceived stress due to extreme self-evaluation of their performance and that their main focus is on the negative aspects of the events that happen to them have a high probability of suffering from depression, these people are due to high fear of rejection and fear of being criticized. Taking from others experience more low self-esteem than people with low self-criticism.

Ahmadi and Rostamnejad (1400) conducted a research entitled "Relationship between self-criticism, fear of failure and social anxiety with low self-esteem of female students of the first secondary level". The findings of the research showed that there is a positive and significant relationship between shyness and fear of failure and with self-criticism and social anxiety. Also, the results indicated that the variables of the research were able to explain 22% of the variable of hypocrisy.

Lewan et al. (2022) [19] conducted a qualitative study titled "Experience among students with social anxiety disorder in social situations". Findings from the analysis of the interviews in 4 topics and several main categories, including distorted self-awareness (3 main categories), fear of negative reaction from others (2 main categories), unfavorable body and mind reaction (4 main categories) and strong desire were classified according to treatment. Cordier et al. (2021) [20] conducted a study entitled "The effect of interventions for social anxiety and hypoactivity in school children: a systematic review and meta-analysis". The meta-analysis found interventions that showed a large effect in reducing the negative consequences of stunting, which is consistent with the existing literature on stunting in school and suggests school age as an ideal developmental stage to target stunting. None of the interventions were delivered in a classroom setting, limiting the ability to compare between in-classroom and out-of-classroom interventions, but highlighting the effectiveness of out-of-classroom interventions. Interventions were often conducted in group sessions, school-based, and included activities such as play, modeling and reinforcement, and clinical methods such as social skills training, psychoeducation, and exposure. The results of the study show that when these methods are used in the school environment and involve peers, the results can be effective in reducing the negative effects of hypocrisy. This is consistent with recommendations that interventions be age-appropriate, consider social development, and use broad, school-based programs that address all students.

Newhouse (2021) [21] conducted a study entitled "Shy or anxious? Examining the effectiveness of school-based interventions for childhood social anxiety". The results of the research showed that social anxiety disorder and hypothermia have many common characteristics, which leads to a discussion about where they differ from each other. In addition, shyness and social anxiety have a significant relationship.

Gang et al. (2021) conducted a study entitled "Holimony and depressive symptoms: a multiple mediation model including core self-evaluation and sense of security". The results of the research showed that low self-esteem has a positive and significant relationship with symptoms of anxiety and depression. Low mood and depressive symptoms had a significant and negative correlation with the feeling of security and the main self-evaluations. And the sense of security had a positive and significant correlation with the main self-evaluations. Core self-evaluations and sense of security played parallel and sequential full mediating effects in the relationship between low self-esteem and depressive symptoms.

According to the developed theoretical framework, the following assumptions can be considered for this research:

The main hypothesis

There is a relationship between self-criticism, social anxiety and shyness among female students of the first year of high school in Shahid Chozoklu School.

Sub-hypotheses

1. There is a relationship between self-criticism and shyness among female students of the first year of high school in Shahid Chuzuklu School.

2. There is a relationship between social anxiety and shyness among female students of the first year of high school in Shahid Chuzuklu School.

3. Research method:

In terms of method, this research is a part of descriptive-correlational research and in terms of purpose, it is considered in the field of applied research. The statistical population of this research consists of all the students of the first year of the first secondary school of Shahid Chozuklu School in Pakdasht city, in the number of 650 people. According to the table Morgan, 241 people were taken as the sample size. A simple sampling method was used to select the samples. The data collection tool was a questionnaire. Jake and Briggs (1990) 14-question shyness questionnaire, Conroy's 41-question fear of failure questionnaire. 2001) the 25-question social anxiety questionnaire of Ilina Jarabek (1996) and the 22-question self-criticism questionnaire of Thompson and Zorov (2004) were used. In this research, the method of evaluating the questions of social anxiety, fear of failure and shyness questionnaires was based on the five-point Likert scale and the self-criticism questionnaire was based on the six-point spectrum. Based on this, ranks 1 to 5 (equivalent to 0 to 6) were assigned to the answers. A score of 1 (equivalent to zero score) indicates the least importance of the question and a score of 5 (equivalent to 6) indicates the highest importance of the question.

In the current research, each of the numbers attributed to the options are considered as the score of that option; Therefore, the sum index has been used to construct the used variables. Data analysis was done using SPSS version 26 and AMOS version 24 software. In the present study, the significance level is 0.05. Statistical methods of confirmatory factor analysis and structural equations have been used to investigate research hypotheses.

4. Research findings

In this section, using the structural equation modeling approach, the proposed model of the research was investigated, and the results are given below. Structural equation modeling is a powerful tool in the hands of the researcher, which helps him in formulating the foundations and theoretical framework of the research in the form of a measurement and structural model.

The output of the software shows the appropriateness of the proposed research model; So that the value of the root mean square of the RMSEA estimation error is equal to (0.064), the value of the normalized chi-square (CMIN/DF) is equal to (2.375) and the value of the goodness of fit index (GFI) is equal to (0.924). Others The indicators for fitting the proposed research model are shown in table 1. The results presented in this table show a significant relationship between self-criticism and shyness variables, $p=0.001$, social anxiety and shyness $p=0.001$. is $\beta=0.316$.

Table No. 1- Fit indices of the proposed model of the main hypothesis of the research

Index of the acceptable limit of the reported value

Normalized chi-square (CMIN/DF) equal to or less than 2.375

Goodness of fit index (GFI) equal to or greater than 0.9 924.0

Modified goodness of fit index (AGFI) equal to or greater than 0.9 0.893

Normalized fit index (NFI) equal to or greater than 0.9 0.962

Incremental fit index (IFI) equal to or greater than 0.978

Tucker-Lewis index (TLI) equal to or greater than 0.973.0

Comparative fit index (CFI) is equal to or greater than 0.978

The root mean square error of estimation (RMSEA) is equal to or smaller than 0.08 0.064

Table No. 2- Examining the relationship between the variables in the main hypothesis of the research

Path coefficient hypothesis p-statistic t-value

Self-criticism → Shyness 0.424 8.355 0.001

Social anxiety → Shyness 0.316 7.278 0.001

The first sub-hypothesis: There is a relationship between self-criticism and shyness among female students in the first year of high school in Shahid Chuzuklu School.

The results show an incremental (direct) and significant effect of self-criticism on shyness, $p < 0.05$, $\beta = 0.424$. In other words, it can be said that with the increase of self-criticism among female students of the first year of secondary school of Shahid Chozoklu School, shyness increases among them.

Table No. 3- Examination of the relationship between the variables in the first sub-hypothesis

Path coefficient hypothesis p-value t statistic

Self-criticism → Shyness 0.424 8.355 0.001

The second sub-hypothesis: there is a relationship between social anxiety and shyness among the female students of the first year of high school in Shahid Chuzuklu School.

The results show an incremental (direct) and significant effect of social anxiety on shyness, $p < 0.05$, $\beta = 0.316$. In other words, it can be said that with the increase of social anxiety among the female students of the first year of secondary school of Shahid Chuzuklu School, their shyness increases.

Table No. 4 - Examining the relationship between the variables in the second sub-hypothesis

Path coefficient hypothesis p-value t statistic

Social anxiety → Shyness 0.316 7.278 0.001

According to the establishment of structural equation modeling assumptions, in this part the results of the structural model will be reviewed. The output of the software shows the appropriateness of the proposed research model; So that the value of root mean square error of estimation (RMSEA) is equal to (0.064), the value of normalized chi square (CMIN/DF) is equal to (2.375) and the value of goodness of fit index (GFI) is equal to (0.924)) Is. Other indicators

for fitting the proposed research model are listed in Table No. 1. In the structural model, no covariance relationship was used to improve the fit indices. Critical ratio has been used to check the significance of research hypotheses. If the critical ratio is greater than 1.96 or less than -1.96 (at an error level of less than 5%), the hypothesis is confirmed and a significant relationship between the two variables is obtained. The presented results show a significant relationship between the variables of self-criticism and shyness ($\beta=0.424$, $p=0.001$), social anxiety and shyness ($\beta=0.316$, $p=0.001$). Due to the positivity of the path coefficients, these relationships are incremental (direct).

5. Discussion

In every society, a significant percentage of teenagers, without having a desire, involuntarily imprison themselves in a fence of shyness, and their real personality and valuable capabilities remain unknown behind shyness. How many intelligent and creative students who in schools and only because of shyness and social disability, always get a lower score than their normal peers in terms of educational progress and the power of creativity and innovation; Because shyness is a serious obstacle to the growth of individual capabilities and creativity. Many factors are effective in the emergence of shyness, some aspects of shyness are the result of learning, and cultural contexts, environment and family conditions, as well as behavioral and social patterns, create a supportive background for the emergence of shyness. Shy people have lower communication quality than non-shy people. Shy people behave impulsively in social interactions and interpersonal relationships, and in other words, they lack social skills and suffer from anxiety in some way. On the other hand, students who pay a lot of attention to the negative aspects of their personality, they consider their weak points to be big and their strong points to be undervalued; This causes their weak perceptions and beliefs to be formed and their shyness to intensify. In this regard, this research was conducted with the aim of reducing shyness among students, especially female students. For this purpose, a main hypothesis and two sub-hypotheses were developed. Main hypothesis: There is a relationship between self-criticism, social anxiety and shyness among female students of the first year of high school in Shahid Chuzuklu School.

The results presented in Table No. 1 show a significant relationship between the variables of self-criticism and shyness, $\beta=0.424$, $p=0.001$, social anxiety and shyness, $\beta=0.316$, $p=0.001$, due to the positive path coefficients, these relationships It is incremental (direct).

The results of the present hypothesis are consistent with the studies of Arzhaneh Dasht et al. In line with the results of this hypothesis, in the research of Dasht Arjeneh et al. (1402), the results showed that self-criticism, in addition to the direct effect through the mediator of competitive anxiety, has a positive and indirect relationship with the fear of failure. Also, early maladaptive schemas have a positive and indirect relationship with the fear of failure in addition to the direct effect through the mediation of competitive anxiety. In the research of Pourjafari and Karimi (1401), the results showed that there is a positive and significant relationship between shyness, social anxiety and tension symptoms with depression. In Rajabi and Abbasi's study (2013), the results showed that there was a significant positive relationship between the variables of self-criticism, social anxiety, and fear of failure with shyness.

The first sub-hypothesis: There is a relationship between self-criticism and shyness among female students in the first year of high school in Shahid Chuzuklu School.

The results show an incremental (direct) and significant effect of self-criticism on shyness, $p<0.05$, $\beta=0.424$. In other words, it can be said that with the increase of self-criticism among female students of the first year of secondary school of Shahid Chozoklu School, shyness increases among them.

The results are consistent with the results of the present hypothesis with the studies of Hasanpour et al. (1401) and Ahmadi and Rostamnejad (1400).

The second sub-hypothesis: there is a relationship between social anxiety and shyness among the female students of the first year of high school in Shahid Chuzuklu School.

The results show an incremental (direct) and significant effect of social anxiety on shyness, $p < 0.05$, $\beta = 0.316$. In other words, it can be said that with the increase of social anxiety among the female students of the first year of secondary school of Shahid Chuzuklu School, their shyness increases.

The results of the present hypothesis are consistent with the studies of Moghadam et al. (1401), Ahmadi and Rostamnejad (1400), Newhouse (2021), Gang et al.

6. Practical research suggestions

According to the results of the research, practical and research proposals are presented as follows:

Considering that the results show that there is a relationship between self-criticism and social anxiety with shyness among female students of the first year of high school in Shahid Chozoklou School; In this regard, it is suggested:

Correct self-criticism training helps students to adequately evaluate themselves, learn from their mistakes, and adequately evaluate their achievements and shortcomings.

- School counselors and psychologists should pay attention to their self-criticism levels while working with these students.

- Parents help their child practice dating skills. Practice these skills using role playing and modeling to teach your child to experience peace with their peers.

- Teachers should note that students who have social anxiety usually have difficulty in making friends. Try to provide conditions where your child can communicate with his peers.

- Teachers should dedicate a few minutes to listen to the concerns and problems that cause students' stress. Help them in this way. Even 5 minutes of talking about concerns, writing them on the board and considering them in lesson planning can be effective in reducing students' stress.

Encouraging students to participate in social activities and group games and shows.

Knowing the student's talents and abilities will strengthen self-confidence and ultimately eliminate shyness.

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Virtual power plant: A review on Components, Models, Types and Scheduling

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ABSTRACT

In the upcoming years, the integration of expanding distributed generations (DGs) and Renewable Energy Sources (RESs) with Energy Storage System (ESS) facilities and also Demand Response Programs (DRP) necessitates the presence of an adaptive power system. A virtual power plant (VPP) stands as an advanced power generation technology that streamlines and enhances generation, network limitations, energy storage devices, and demands. It brings substantial enhancements in power system flexibility, enhances the efficient use of distributed generations on the user-side, and promotes advancements in wholesale markets. Despite its promise, VPP is presently in its nascent phase of development. These aforementioned technologies are changing the energy landscape, with decentralized energy generation through virtual power plants (VPPs) idea becoming a major trend. VPPs combine small-scale distributed units to act as a single and independent entity. This study examines key issues related to VPPs, including definitions, components, optimization, scheduling problem and types such as commercial VPPs and technical VPPs.

Keywords: Virtual power plant, Renewable energy, Distributed energy resource, Scheduling, Energy Storage System

1.INTRODUCTION

Over the recent decades, there has been a notable increase in Distributed Generations (DGs), Renewable Energy Sources (RESs), Energy Storage Systems (ESSs) at the distribution level, and Demand response (DR) programs, presenting new challenges for network operators while also providing a transformative opportunity for the grid. Modern DG technologies, incorporating RESs, have undergone significant advancements, such as improved solar cell efficiency, higher wind generator capacities, the evolution of advanced Combined Heat and Power (CHP) systems, progress in fuel cell technologies, enhanced efficiency and capacity of ESSs, and the introduction of innovative RESs like tidal generators and small hydro generators [1].

Meanwhile, the ongoing progression towards the liberalization of the electricity market, transitioning from a monopolistic system to competitive market frameworks, is garnering increasing attention [2]. In light of these dual trends, the operation of a large quantity of DER units under market conditions are unavoidable, presenting new challenges that must be tackled, including:

- Market participation: Despite being viewed as small, adaptable power sources, storage technologies, and controllable loads [3], DERs are typically restricted from entering the existing electricity market [4].

- Stochastic characteristics: Given that numerous DER technologies such as solar panels and wind turbines rely on weather conditions, their variable output is deemed non-dispatchable, limiting their role in grid operations and leading to economic penalties stemming from unforeseen imbalances.

- Isolation: Many DER units operate independently due to differing ownership structures. Collaboration and communication between adjacent DER units are often lacking, constraining the capacity of DERs to meet local demands rather than the broader grid requirements.

One strategy to tackle these challenges is to aggregate multiple DER units within a Virtual Power Plant (VPP). Through this arrangement, the cluster of DER units can exhibit the same level of observability, controllability, and market functionality as traditional transmission-connected power plants [5]-[10].

Power can be distributed through different methods, yet customers seek top-notch quality, minimal expenses, and unparalleled dependability. VPPs stand out as notable solutions for ensuring a dependable electricity supply in a power system. As this system incorporates distributed energy resources (DERs), effective arrangement of these assets becomes crucial [11,12]. It is projected that many market participants engage in numerous activities with this platform [13].

1.1. Definition and concept (Literature Review)

In fact, VPP is currently in the speculation phase and there is no solitary description for the structure of VPP in the literary works. In [14] VPP is characterized identically to an independent micro-grid. In [7], VPP is depicted as a collection of various kinds of spread-out resources that might be scattered across different locations within the medium voltage distribution network. In [15], VPP is comprised of a variety of technologies with diverse operational behaviors and availability, enabling them to link up with different points of the distribution network. In [16] VPP is defined as a multi-technology and multi-location diverse entity. In the FENIX project, the concept of VPP is articulated as follows: "A VPP consolidates the capabilities of numerous distinct DERs, forming a unified operational profile derived from a blend of the characteristics defining each DER, and can factor in the network's influence on the collective output of DERs. A VPP serves as a versatile representation of a collection of DERs that can be utilized for contractual agreements in the wholesale market and for providing services to the system operator [15]."

Here we describe the general idea of the VPP as follows:

A Virtual Power Plant (VPP) is an idea that integrates dispersed generator units combining fossil and renewable sources, controllable loads, and storage systems to function as a unified power entity which managed by an Energy Management System (EMS) through bi-directional communication empowers real-time monitoring and control, elevating operational efficiency, stability and flexibility of distribution grid.

Lately, numerous literary appraisals have been published in the realm of VPP concept, with a specific focus on DERs to address power system concerns. The following section provides a review of some of these publications.

In [17] a comprehensive review of VPP ideas is presented and also offers an overall summary of VPP concepts. Authors of [18] examines the obstacles and issues arising from the discharging or charging of plug-in electrical vehicles. It explores the potential of electric vehicles as a solution for integrating RESs and Demand Response programs (DR) in grid. Reference [19] presents a review of modeling the uncertainty modes used in power system analysis, discussing the strengths and weaknesses of these methods. In [20], the researchers focused on improving the scheduling of a market-driven virtual power plant to increase profitability and reduce procurement costs. In contrast, reference [21] introduced a new market bidding mechanism for VPPs to manage the balancing energy market. Reference [22] assessed a VPP in the energy market combining RESs, ESSs, and demands to optimize societal welfare. Reference [23] studied interconnected AC-DC microgrids to enhance societal welfare, while reference [24] explored VPPs acting as price setters to mitigate real-time market penalties. Additionally, reference [25] investigated a multi-

objective bidding scheme for virtual power plants involving Wind Turbines (WTs) and Photovoltaics (PVs), reference [26] put forward a strategy to maximize profits for VPPs in demand response programs, and reference [27] examined the characteristics of virtual power plants providing flexibility services in distribution systems. Furthermore, reference [28] proposed a method for multi-level market contracts defining VPP associations, considering VPP collaboration while addressing uncertainties related to distributed generations. The authors of [29] expanded a model focused on retail to analyze the dispatch capabilities of WTs, PVs, and ESSs to optimize societal welfare for customers. Lastly, the authors of reference [30] evaluated the impact of demand-side management programs along with ESS facilities on the internal power market of VPP and locational marginal prices. Examining different explanations and fundamental concepts of Virtual Power Plants, its key elements, and ultimately two main forms of VPPs, commercial VPPs (CVPPs) and technical VPPs (TVPPs) described in [31].

a. Research Gap

In many of the articles discussed in the literature, there are weaknesses and unspoken aspects, one of which is that a virtual power plant does not necessarily take geographical distance into account, and this is its advantage over other smart grid concepts like microgrids. However, this does not mean that any distance is not a concern at all; rather, it refers to, for example, the geographical distance within a distribution or transmission network.

Another aspect is that the idea of a VPP is not solely for the participation of small capacity units in the electricity market, but one of the advantages of this concept is participation in the energy market. It could be argued that one of the main benefits of a VPP is to assist in enhancing the flexibility of the distribution network towards ensuring a more reliable electricity supply.

Failure to consider the consistent output of a VPP when participating in the energy market and other markets is another weakness identified in the literature review. Essentially, most studies on VPPs in the electricity market focus on displaying the dispatch results of units under the virtual power plant's supervision, rather than the monolith output of the VPP every hour of the day and night for market participation or other services.

Additionally, the operator of a VPP and the operator of the distribution network can be the same entity, in which case the VPP, besides considering the operational constraints of the network, is required to supply all its loads. Furthermore, by considering a smaller area within the network, it can aggregate production and supply loads under its supervision and also interact with the upstream distribution network for electricity service trading. Therefore, the realization of the VPP concept is not solely achieved through participation in the electricity market; rather, one of the realizations of the VPP idea is participation in the energy market.

In the following sections, we will provide an overview of the key components and capabilities of a virtual power plant, as well as its types and planning and solving methods.

24. Scheduling Issues Related to Mathematical Model and Optimization Goal

In the power systems, the integration of innovative management techniques and DERs taking into account security, quality, reliability, and power accessibility leads to a shift from static to dynamic grid operations, emphasizing the VPP concept. As DER penetration in power systems grows rapidly, particularly in grid management, offering ancillary services and enhancing grid performance become crucial. Thus, introducing innovative approaches to control generation and facilitate their involvement in electricity markets is essential. The VPP concept emerges as a suitable solution to address these challenges.

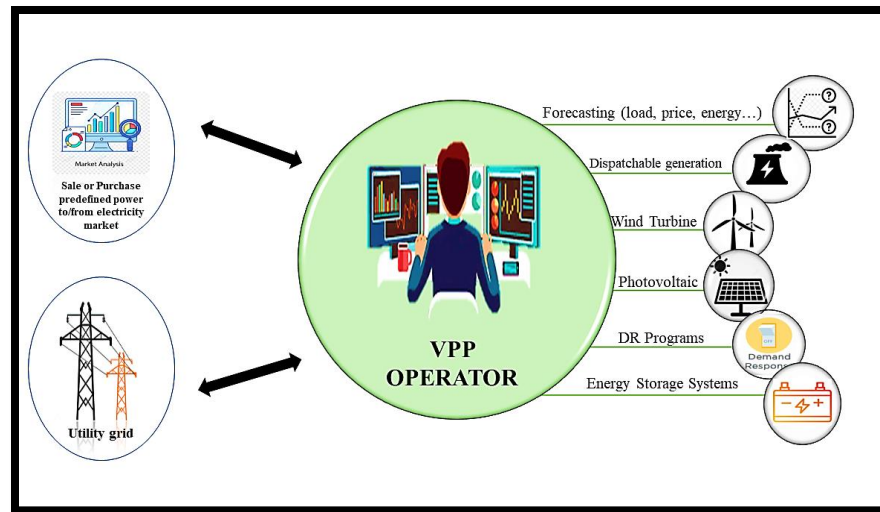


Fig. 1. A Typical VPP structure.

Fig. 1 illustrates the composition of a VPP concerning the aggregation of DERs. In such setup, the aggregator offers a profile of production derived from dealings with various electricity producers, taking into account their anticipated power production profiles. The process depicted in the figure involves numerous intricacies, including predictive algorithms and the coordination of system elements according to their technical and financial characteristics [13].

Overall, two different categories of formulations are typically considered for addressing efficient scheduling challenges: stochastic modeling and deterministic and robust optimization. Stochastic formulations for optimal management problems in VPPs are addressed in references [32-37], and deterministic formulations for VPP frameworks are defined in references [38-42]. A stochastic approach for solving the scheduling and determining optimal bids in a VPP is demonstrated in Fig. 2. This strategy involves receiving various scenarios, minimizing them to a manageable figure, performing stochastic optimization, and deriving optimal energy bids based on the complete stochastic process.

The primary purpose of a VPP is to maximize its revenue by optimizing the scheduling of DERs while adhering to the constraints of the grid. As a VPP curtails or shift its load in DR programs, the reduced load can be considered as virtual generation. Various types of DERs, when operating individually, may lack the capacity, flexibility, and control necessary for effective management for a system and marketing engagements.

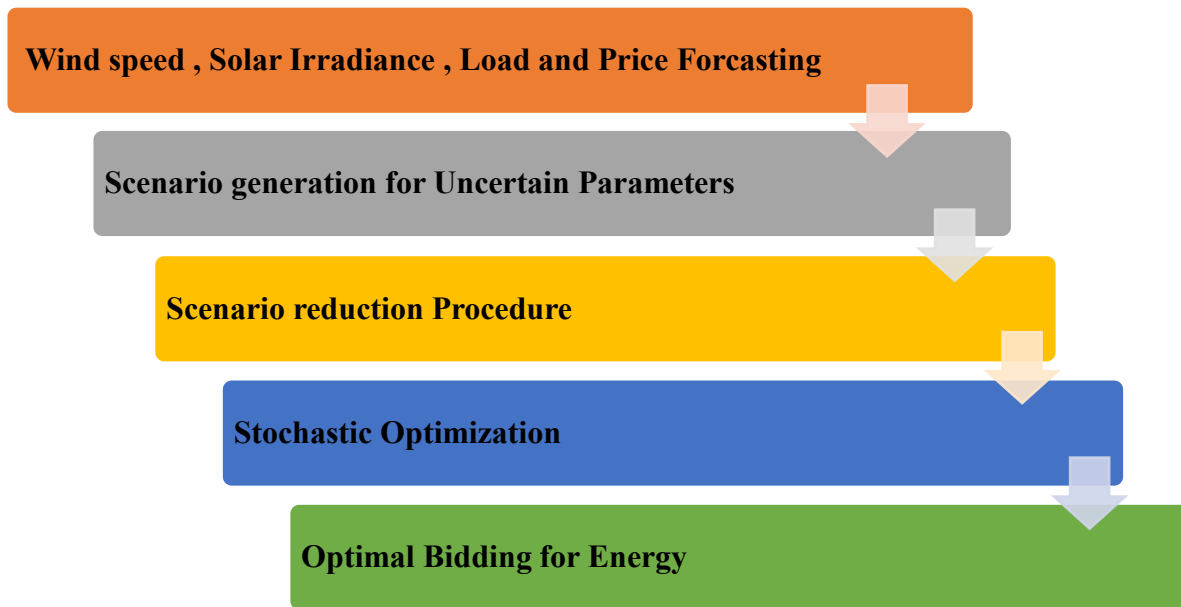


Fig. 2. Optimal energy bidding in a VPP.

This issue Can be tackled through consolidation these resources and flexible load demands into a virtual power plant.

Typically, the scheduling of DERs in a VPP is formulated as an optimization problem, often represented in the form of an equation (Eq. 1). This optimization problem seeks to maximize its profit by determining the optimal operation of DERs, considering factors such as energy production, consumption, market prices, and system constraints. By aggregating multiple DERs and flexible loads into a VPP, the overall efficiency and profitability of the system can be enhanced, enabling better participation in energy markets and grid services [43-44].

$$OF = \text{Maximizing Profit} / \text{Minimizing Cost}$$

subject to:

$$\text{Diverse optional and/or compulsory Constraints} \quad (1)$$

25. VPP COMPONENTS

a. Generation

The Virtual Power Plant comprises three main components, starting with the Generation Technology. Distributed Generation technologies like Combined Heat and Power (CHP), biomass, small power plants, small-sized hydro-plants, wind energy, solar production, and controllable loads fall under the DG category. DG units can be classified as Domestic Distributed Generators (DDGs) serving individual consumers and Public Distributed Generators (PDGs) injecting power into the grid. Both DDGs and PDGs can include energy storage. DDGs are typically connected to low voltage distribution networks, while PDGs are connected to medium voltage networks. DDGs aim to meet their own energy needs and enhance reliability, while PDGs aim to sell their power to network customers. DDGs have smaller capacities compared to PDGs, limiting their ability to participate in power markets independently. Some DGs, for instance wind turbines (WTs) and photovoltaics (PVs), are stochastic, while others like fuel cells and micro turbines

are dispatchable. PDGs and DDGs can be further categorized as Dispatchable PDGs (DPDGs), Stochastic PDGs (SPDGs), Dispatchable DDGs (DDDGs), and Stochastic DDGs (SDDGs) [31].

b. Storage facilities

Today, energy storage systems are increasingly recognized as a vital tool for balancing fluctuations in power demand with varying levels of electricity production. Within the realm of RESs, these facilities may function as supplementary energy reservoirs, particularly for non-dispatchable or stochastic production like WTs and PV facilities, particularly in areas with fragile networks. ESSs contemplated for assimilation in VPPs include:

- Battery Energy Storage System (BESS)
- Hydrogen coupled with Fuel Cell (FC) technologies
- Flywheel Energy Storage (FWES)
- Compressed Air Energy Storage (CAES)
- Supercapacitor Energy Storage (SCES)
- Hydraulic Pumped Energy Storage (HPES)
- Superconductor Magnetic Energy Storage (SMES)

These diverse ESS facilities play a pivotal function in enhancing the flexibility and efficiency of VPPs, enabling better assimilation of RESs into the network and ensuring stability in power supply.

c. Information Communication Technology (ICT)

Effective communication technologies and foundation are crucial necessities for VPPs. Various communication media facilities might be utilized for intercommunication across Energy Management Systems (EMS), Supervisory Control and Data Acquisition (SCADA), and Distribution Dispatching Center (DCC). These technologies play a vital role in enabling seamless coordination, control, and data exchange within the VPP, ensuring efficient management of power generation, distribution, and monitoring. These systems are used for monitoring and controlling the performance of electricity generation units and for optimizing electricity production consumption planning.

26. TYPES OF VIRTUAL POWER PLANTS

a. Technical VPP (TVPP)

The TVPP is a system that comprises DERs from the same geographic area. It incorporates the real time impact within the local grid on the aggregated DERs profile and depicts the cost and operational attributes of the portfolio. The TVPP offers merits and operations such as domestic system administration for the Distribution System Operator (DSO) and provides flexibility and ancillary services for the Transmission System Operator (TSO). Operator of a TVPP needs comprehensive data regarding the local grid, usually obtained from the DSO [47].

Key features of a VPP include [48]:

- Observability of DER units to the network operators
- Involvement of DER units in system oversight

- Maximizing the efficient use of DER unit capacity to offer ancillary services, taking into account limitations within the local network.

By leveraging these capabilities, a VPP enables efficient coordination and utilization of DER resources within a specific geographic area, enhancing overall system flexibility and reliability.

The use of the TVPP concept permits small-sized units to offer ancillary services, thereby reducing risks of unavailability through portfolio diversification and capacity aggregation in contrast to standalone DER units. A detailed analysis of the technological monitoring abilities of DERs and their potential to provide ancillary services is conducted in research studies [49] and [50]. This analysis includes assessing the technological potential by considering the grid-interconnected converter individually with its unique abilities, revealing significant technological opportunities. DSOs implementing the TVPP idea can also operate as Active Distribution Network (ADN) operators [51]. An ADN operator can leverage ancillary services provided by DERs to optimize network performance. Additionally, ADN operators can provide ancillary services to other network operators, enhancing overall system flexibility and reliability. The TVPP concept can lead to the establishment of hierarchical or parallel ADN structures based on various voltage levels or network zones, enabling efficient coordination and utilization of DER resources. Numerous instances of ADNs are cataloged in the active network implementation Register [48].

The TVPP is responsible for performing various essential functions, including continuously monitoring equipment conditions and retrieving historical load data, managing assets with statistical support, enabling self-recognition and qualification of network elements, integrating fault detection coupled with outage management, facilitating maintenance, and conducting statistical analysis for optimization of project portfolios.

b. Commercial Virtual Power Plant (CVPP)

A CVPP aggregates the characteristics and results of DER to depict the cost and operational attributes of the DER portfolio. The aggregated CVPP profile does not account for the influence of the distribution network. Services offered by a CVPP encompass wholesale energy market trading, portfolio balancing, and providing services to the transmission system operator through bids and offers. A third-party aggregator or a Balancing Responsible Party (BRP) with market access, like an energy provider, could manage a CVPP. The CVPP facilitates [47,48]:

- Observability of DERs within energy markets,
- allows DERs to participate in wholesale markets,
- maximizes the benefit obtained from the involvement of DER units in wholesale markets.

By enabling market entry for small-sized units and leveraging portfolio diversity and capacity, CVPPs help reduce the risk of imbalance compared to individual DER units operating in isolation. CVPPs focus on commercial aggregation and may not address the network operation aspects crucial for stable operation, as active distribution networks must [52]. The aggregated DERs are not restricted by placement and can be dispersed across different distribution and transmission networks. As a result, a sole distribution network zone might have multiple CVPPs aggregating DER units within its area.

Primary functionalities of a CVPP include optimizing and scheduling generation derived from forecasted consumer load demand and production capacity. Once actual demand deviates from predictions, Demand Response Resources (DRRs) are utilized to bridge the disparity between generation and actual consumption. Additionally, CVPP functions typically involve maintaining and submitting characteristics of DERs, forecasting production and

consumption, managing demand during outages, developing bids of DERs, submitting market bidding, daily optimization, and scheduling of generation, and facilitating the sale of energy from DERs to the market.

27. Scheduling Problem Related to Solving Methods

When defining an optimization model for a scheduling problem, several challenges arise in finding a solution. Initially, diverse input data must be gathered, and then an appropriate method needs to be chosen to solve the optimization model. In the context of addressing optimal scheduling problems in VPPs, a variety of methods have been utilized. These approaches could be broadly categorized into two primary approaches: mathematical optimization approaches and heuristic optimization approaches.

solving methods in virtual power plants include optimization algorithms, demand and supply management, energy management, and intelligent systems. The goal of these methods is to improve the efficiency and performance of the virtual power plant and increase flexibility in electricity production. These methods utilize advanced computational and data analysis techniques.

Mathematical optimization methods pertinent to VPPs can be delineated as follows:

- Mixed integer linear programming [33-35]
- Primal-dual sub-gradient algorithm [40]
- Fuzzy simulation and crisp equivalent [42]
- Game theory [49]
- Linear programming [53, 54,55]
- Nonlinear programming [56]
- Event-driven service-oriented framework [56]
- Mixed integer nonlinear programming [57, 58]
- Point estimate method [34, 57]
- Interior point method and primal-dual sub-gradient algorithm [39,59]
- Branch-and-bound method [60, 61]
- Decision Tree [32, 62]
- Hierarchical structure [63, 64]
- Dynamic programming [65]
- Quadratic programming [60, 66]
- Area-based observe and focus algorithm [67]

28. CONCLUSION

The VPP idea enables individual DERs to access and participate in various energy markets, Leveraging VPP market intelligence for optimization their positions and maximizing income possibilities. This approach benefits grid operations by efficiently utilizing available capacity and enhancing overall operational efficiency. Stakeholders across different sectors stand to gain from the Virtual Power Plant concept:

Owners of DERs:

- Capture flexibility value
- Increase asset value
- Reduce financial risk
- Improve negotiation abilities

DSOs and TSOs:

- Gain visibility of DERs
- Utilize control flexibility
- Enhance grid investments
- Coordinate DSO and TSO efforts
- Address operational complexities

Policy Makers:

- Integrate renewables cost-effectively
- Open energy markets to small-scale participants
- Enhance system efficiency
- Support renewable energy goals
- Improve consumer choice
- Create new job opportunities

Suppliers and aggregators:

- Offer new services
- Reduce commercial risk
- Explore new business opportunities

Hence, it is crucial to emphasize that a virtual power plant serves as both a strategic concept for the integration of low-capacity units into the electricity market and as an autonomous entity for the planning, optimization, and efficient aggregation of dispatchable and non-dispatchable units, as well as demand response programs at the distribution network level that upon its specific application it serves as technical or commercial type.

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Enhancing Operational Reliability and Efficiency in Architectural and Automotive Glass Production through Integration of Tempering-Furnace Power-Driving UPS with SCADA System

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ABSTRACT

The integration of Uninterruptible Power Supply (UPS) with Supervisory Control and Data Acquisition (SCADA) system plays a crucial role in ensuring reliable power supply to the furnace during the glass tempering process, thereby optimizing production processes and minimizing downtime. This study showcases a successful implementation of this integration in a manufacturing setting, in the context of architectural and automotive glass production, highlighting the benefits of improved operational reliability, enhanced efficiency, and sustainable manufacturing practices. Providing a comprehensive study into the integration process including the appropriate physical layer, the TCP/IP layer, and the Simple Network Management Protocol (SNMP) corresponding to the application layer of the OSI model, this article provides paramountly valuable insights for industry professionals and researchers seeking to enhance operational performance in glass manufacturing facilities.

Keywords: UPS, SCADA, reliability, efficiency, furnace, tempering, glass

1.INTRODUCTION AND PROBLEM STATEMENT

1.1 Introduction

The production of architectural and automotive glasses holds a significant place in the global industrial and economic landscape. These specialized glasses play a crucial role in the construction of buildings and the manufacturing of vehicles, contributing to both functional and aesthetic aspects. Architectural glass is essential for creating modern, sustainable structures with innovative designs, while automotive glass ensures safety, visibility, and comfort for drivers and passengers. The production of these glasses involves advanced technologies and materials, with manufacturers constantly innovating to meet the evolving demands of the market [1, 2].

According to a report by Grand View Research, the global architectural glass market size was valued at USD 83.51 billion in 2020 and is projected to reach USD 125.32 billion by 2028, growing at a CAGR of 5.2% from 2021 to 2028. The automotive glass market is also experiencing significant growth, with a projected value of USD 25.8 billion by 2025, according to a study by Research and Markets. These statistics highlight the substantial economic impact of architectural and automotive glass production on a global scale. Furthermore, advancements in technology, such as the development of smart glass and self-healing glass, demonstrate the continuous innovation within the industry to meet the changing demands of consumers and ensure the safety and sustainability of structures and vehicles [1, 2].

1.2 Problem Statement

In the manufacturing industry, especially in the production of architectural and automotive glass, tempering and bending furnaces play a crucial role in heating and cooling glass to create strong, durable, and impact-resistant products. However, a key challenge that these furnaces face is power disruptions. Any interruption or fluctuations in power supply can lead to downtime, product wastage, and loss of revenue.



Fig. 1. Architectural and automotive glass production lines
(glass loading section – entry of the furnace) at Venus Glass factory, respectively



Fig. 2. Last section of a furnace for automotive glasses (front side) where the blowers inject the compressed air over the hot glass (courtesy of Venus Glass Co.)

For example, during a power outage in glass production, a critical concern that may arise often is the adhesion of heated and softened glass sheets or pieces to the ceramic rods and rails of the conveyor system. This phenomenon is attributed to the sudden loss of power, resulting in the deactivation of heating elements and rapid cooling of the glass, leading to its adherence to the conveyor components. Addressing this issue reactively, it typically involves either the complete replacement of the costly ceramic rods or rails of the conveyor, or the labor-intensive process of scrubbing and polishing to eliminate the cooled glass residue.

However, an Uninterruptible Power Supply (UPS) can help prevent the issue and ensure that the heating elements in the glass production process remain active even in the event of a power failure, if the electrically behavioral characteristics of the UPS is transmitted to the Supervisory Control and Data Acquisition (SCADA) system for continuous condition monitoring by board men [3].

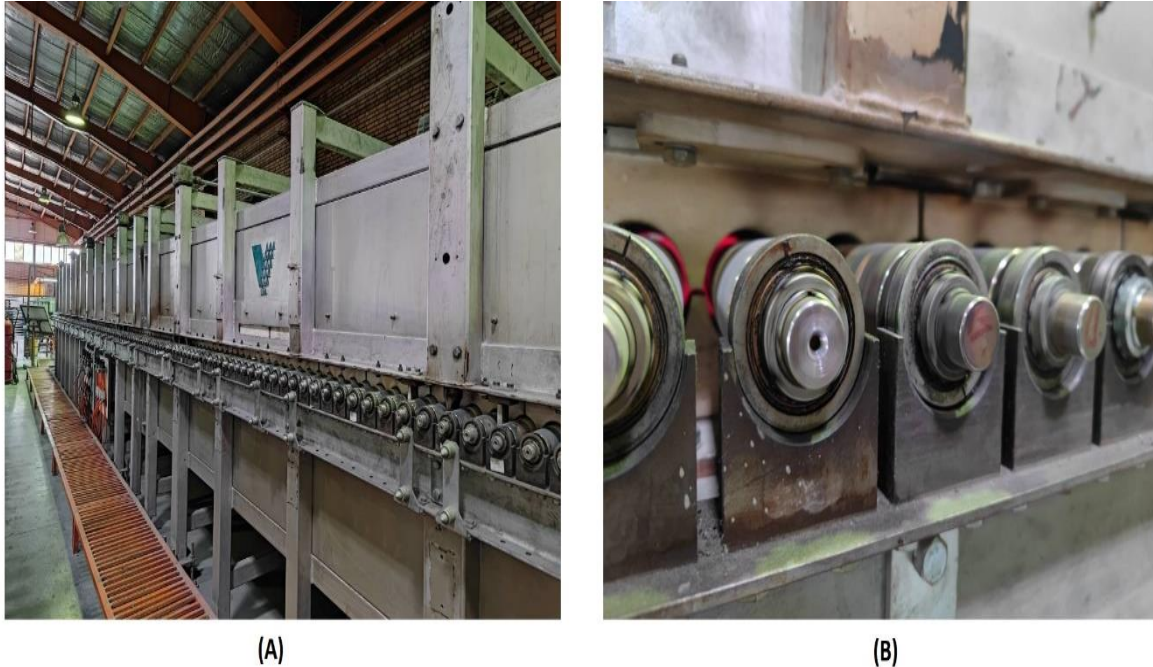


Fig. 3. A tempering and bending furnace for automotive glasses, courtesy of Venus Glass Co. (A) the long heating section of the furnace at a glance, (B) a close-up image of the ceramic conveyor rolls

One notable issue pertains to the necessity for ceramic conveyors to be cooled gradually and uniformly. Nonetheless, when a power outage occurs, what happens to a ceramic plate or rod as different sections cool at varying rates? Uneven thermal stress is induced within the material as distinct parts of a ceramic sheet experience disparate cooling rates. This disparity can result in warping, cracking, or even shattering of the plate. The uneven cooling process may generate internal stresses within the material, leading to deformation or breakage. Therefore, it is imperative to ensure that ceramic rods and rails undergo uniform cooling to mitigate these potential challenges, while turning off the furnace or when the electrical supply is cut out.



Fig. 4. A close-up image emphasizing on the ceramic conveyor rolls coupled with metal pliers in both ends of the ceramic (original image depicted at 200% color saturation and 50% sharpening correction)

An Intricate challenge to confront afterwards with significant consequences is the occurrence of blackouts in the furnace system, resulting in the erasure of controlling parameters in the PLCs and panels. While industrial computers and controllers are equipped with emergency batteries and non-volatile storage technology for data retention, certain configurations executed by operators or changes made by maintainers will be lost if the power supply to the furnace control system is disrupted [4].

Moreover, the UPS system can provide critical data on power consumption and usage, both in real-time and historical data-acquisition regimes, if connected to a SCADA system, helping manufacturers to identify potential inefficiencies and optimize energy consumption. Furthermore, SCADA systems offer remote condition monitoring and diagnostics as well as control capabilities, allowing operators to manage approximately any situation from a safe distance and respond quickly to any issues or emergencies.

To the best knowledge of the authors, the consolidated and definitive solution to these challenges for tempering furnaces is the integration of a UPS with a SCADA system. By adopting and exercising a SCADA-communicating UPS system for tempering furnaces, manufacturers can ensure continuous power supply even in the event of power fluctuations. This not only minimizes production downtime but also protects the quality of the glass being tempered.

The subsequent segments of this research article will be structured as follows: moving on to the second section, a thorough elucidation of our solution as well as recommendations for manufacturers will be expounded upon with intricate detail and precision. The concluding remarks, expressions of gratitude, and list of references will be delineated in sections three, four, and five, respectively, to provide a comprehensive overview of the study.



Fig. 5. A SCADA-communicating UPS system integrated with a tempering furnace

1. SOLUTION PROPOSAL

The solution proposal outlines a comprehensive approach to integrating UPS with SCADA, focusing on the physical layer, TCP/IP layer, and Simple Network Management Protocol (SNMP) within the OSI model.

2.1 Physical Layer Optimization

Link: <https://scieropub.com/pv/DSI141258475746>

The first step in this integration process involves ensuring a robust physical layer infrastructure. This includes deploying high-quality networking equipment, such as switches, routers, and cables, to support seamless communication between the UPS, SCADA system, and the furnace. By optimizing the physical layer, we can minimize latency, enhance data transmission speeds, and improve network reliability, thereby ensuring uninterrupted power supply to the furnace [5].



Fig. 6. Backplate of a UPS containing different sockets or communication endpoints for different communication protocols

2.2 TCP/IP Layer Configuration

Optimizing the TCP/IP layer is crucial for efficient data transmission and communication between the UPS and the SCADA system. By implementing advanced networking protocols and configurations, we can streamline data exchange, enhance network security, and improve overall system performance. Configuring the TCP/IP layer effectively will enable real-time monitoring and control of the UPS, ensuring reliable power supply to the furnace during the glass tempering process [6, 7].

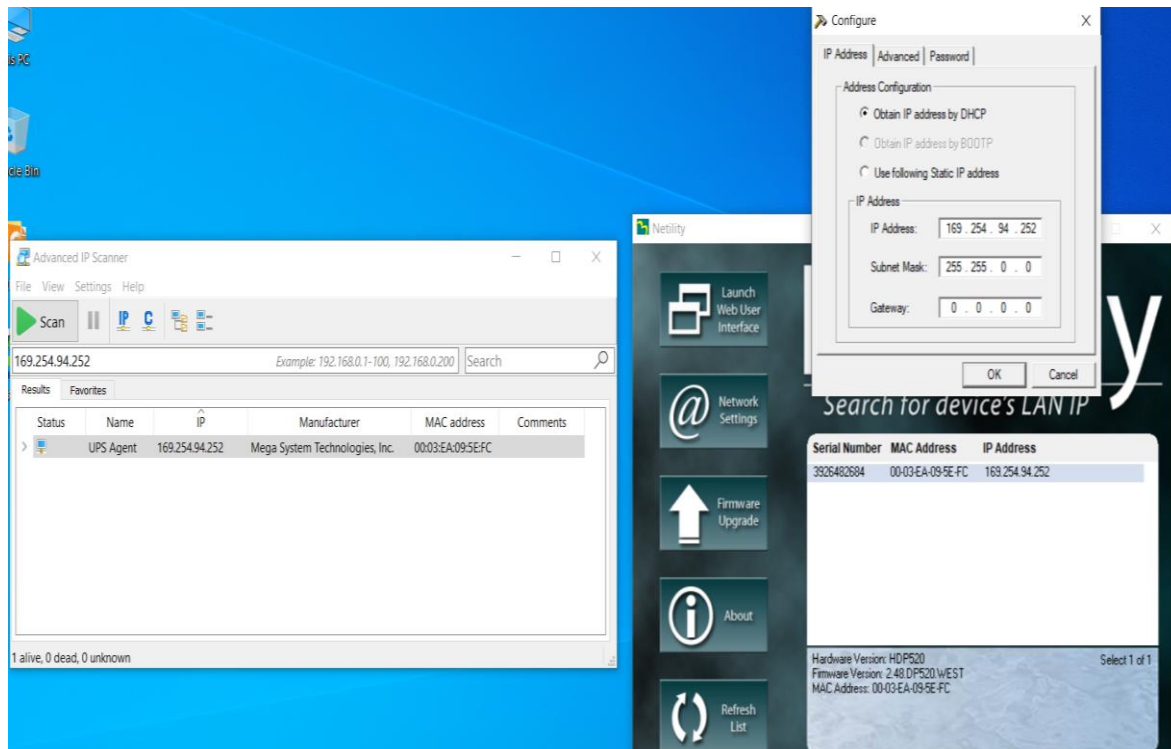


Fig. 7. TCP/IP Layer Configuration

2.3 Integration of SNMP for Enhanced Monitoring

Integrating the Simple Network Management Protocol (SNMP) into the application layer of the OSI model allows for comprehensive monitoring and management of the UPS and SCADA system. By leveraging SNMP, industry professionals and researchers can monitor power supply status, track system performance metrics, and receive alerts in case of any anomalies or failures. SNMP integration provides valuable insights into system operations, enabling proactive maintenance and troubleshooting to minimize downtime and optimize production processes [8, 9].

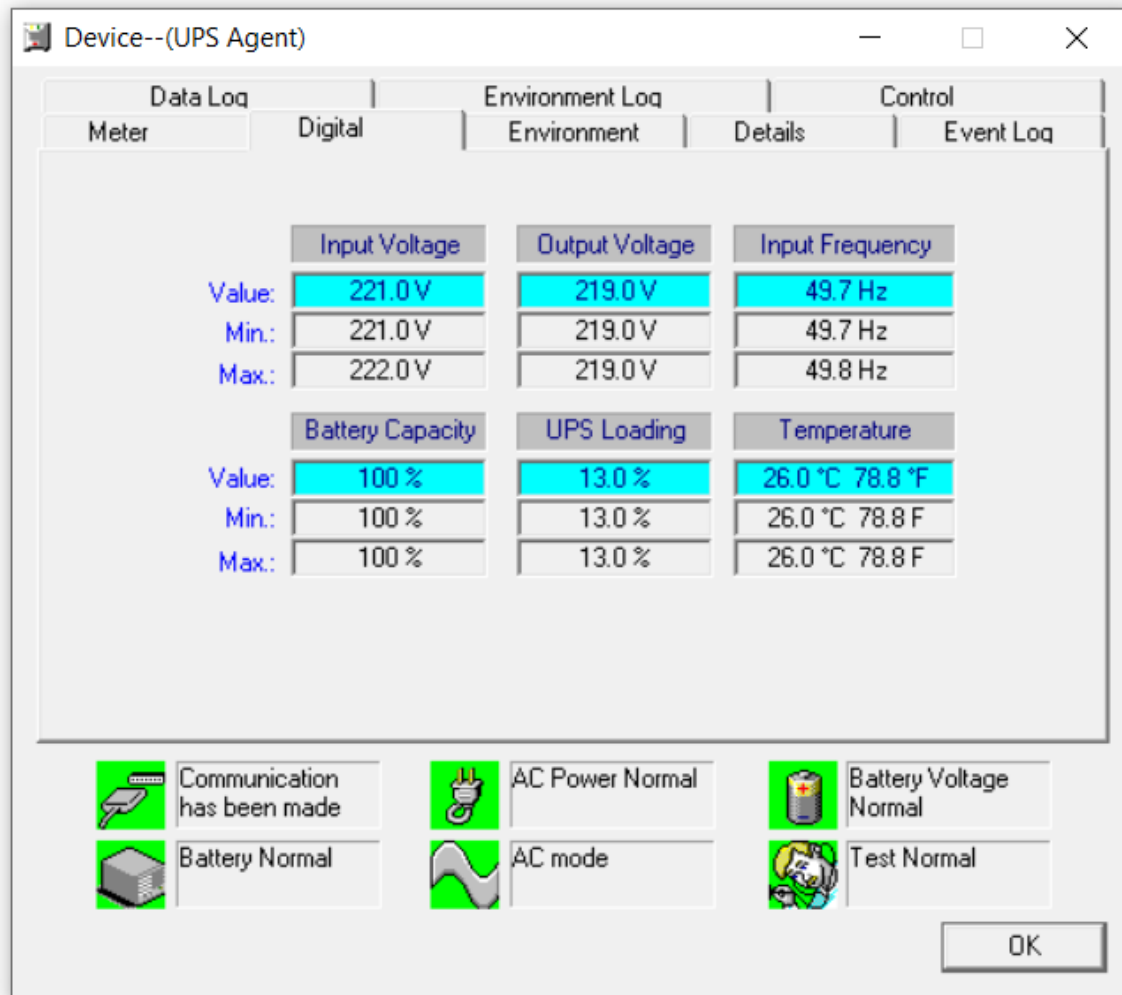


Fig. 8. SCADA Human Machine Interfaces (HMIs) for UPS (A) – Critical overall parameters

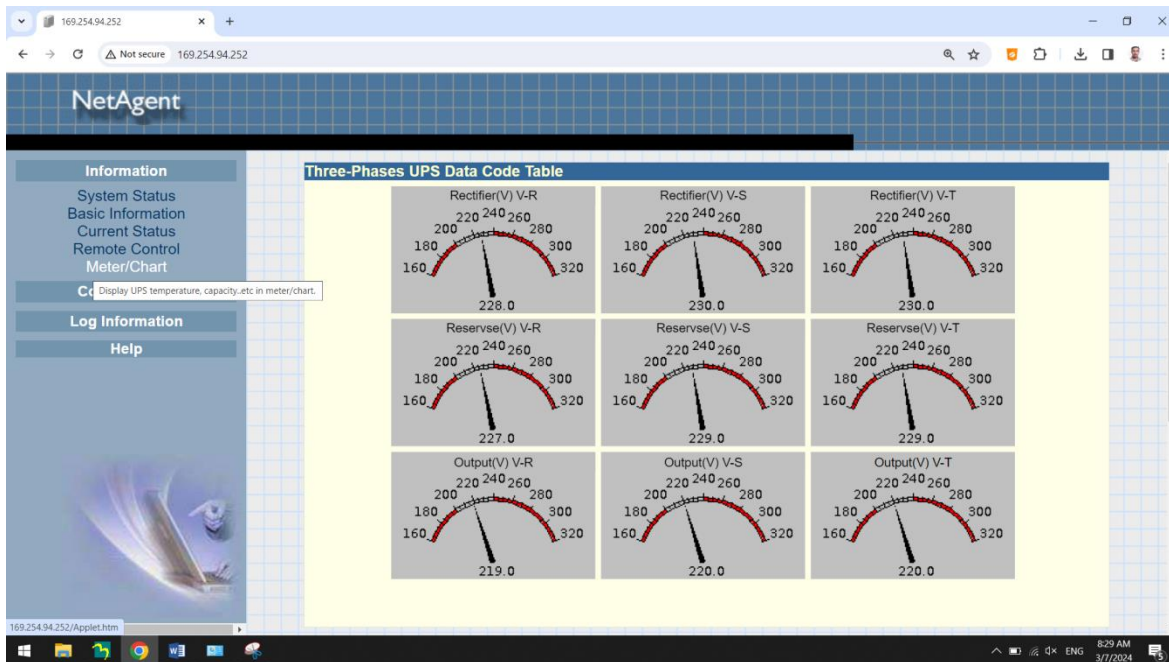


Fig. 8. SCADA Human Machine Interfaces (HMIs) for UPS (B) –
Realtime and online Gauges

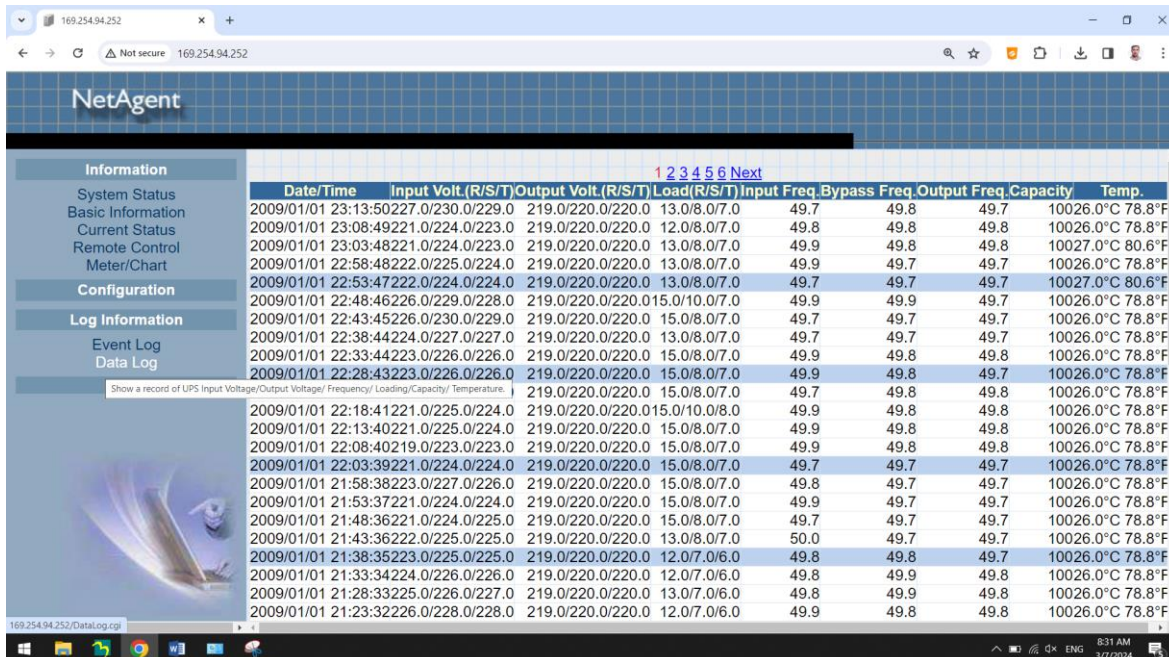


Fig. 8. SCADA Human Machine Interfaces (HMIs) for UPS (C) –
Demonstration of historical data export from SCADA to database

	A	B	C	D	E	F	G	H	I
	Date/Time	Input Voltage(R/S/T)	Output Voltage(R/S/T)	Load(R/S/T)	Input Freq.	Bypass Freq.	Output Freq.	Capacity	Temp.
3	2009/01/01 23:13:50	227.0/230.0/229.0	219.0/220.0/220.0	13.0/8.0/7.0	49.7	49.8	49.7	100	26.0°C 78.8°F
4	2009/01/01 23:08:49	221.0/224.0/223.0	219.0/220.0/220.0	12.0/8.0/7.0	49.8	49.8	49.8	100	26.0°C 78.8°F
5	2009/01/01 23:03:48	221.0/224.0/223.0	219.0/220.0/220.0	13.0/8.0/7.0	49.9	49.8	49.8	100	27.0°C 80.6°F
6	2009/01/01 22:58:48	222.0/225.0/224.0	219.0/220.0/220.0	13.0/8.0/7.0	49.9	49.7	49.7	100	26.0°C 78.8°F
7	2009/01/01 22:53:47	222.0/224.0/224.0	219.0/220.0/220.0	13.0/8.0/7.0	49.7	49.7	49.7	100	27.0°C 80.6°F
8	2009/01/01 22:48:46	226.0/229.0/228.0	219.0/220.0/220.0	15.0/10.0/7.0	49.9	49.9	49.7	100	26.0°C 78.8°F
9	2009/01/01 22:43:45	226.0/230.0/229.0	219.0/220.0/220.0	15.0/8.0/7.0	49.7	49.7	49.7	100	26.0°C 78.8°F
10	2009/01/01 22:38:44	224.0/227.0/227.0	219.0/220.0/220.0	13.0/8.0/7.0	49.7	49.7	49.7	100	26.0°C 78.8°F
11	2009/01/01 22:33:44	223.0/226.0/226.0	219.0/220.0/220.0	15.0/8.0/7.0	49.9	49.8	49.8	100	26.0°C 78.8°F
12	2009/01/01 22:28:43	223.0/226.0/226.0	219.0/220.0/220.0	15.0/8.0/7.0	49.9	49.8	49.7	100	26.0°C 78.8°F
13	2009/01/01 22:23:42	222.0/226.0/225.0	219.0/220.0/220.0	15.0/8.0/7.0	49.7	49.8	49.8	100	26.0°C 78.8°F
14	2009/01/01 22:18:41	221.0/225.0/224.0	219.0/220.0/220.0	15.0/10.0/8.0	49.9	49.8	49.8	100	26.0°C 78.8°F
15	2009/01/01 22:13:40	221.0/225.0/224.0	219.0/220.0/220.0	15.0/8.0/7.0	49.9	49.8	49.8	100	26.0°C 78.8°F
16	2009/01/01 22:08:40	219.0/223.0/223.0	219.0/220.0/220.0	15.0/8.0/7.0	49.9	49.8	49.8	100	26.0°C 78.8°F
17	2009/01/01 22:03:39	221.0/224.0/224.0	219.0/220.0/220.0	15.0/8.0/7.0	49.7	49.7	49.7	100	26.0°C 78.8°F
18	2009/01/01 21:58:38	223.0/227.0/226.0	219.0/220.0/220.0	15.0/8.0/7.0	49.8	49.7	49.7	100	26.0°C 78.8°F
19	2009/01/01 21:53:37	221.0/224.0/224.0	219.0/220.0/220.0	15.0/8.0/7.0	49.9	49.7	49.7	100	26.0°C 78.8°F
20	2009/01/01 21:48:36	221.0/224.0/225.0	219.0/220.0/220.0	15.0/8.0/7.0	49.7	49.7	49.7	100	26.0°C 78.8°F

Fig. 8. SCADA Human Machine Interfaces (HMIs) for UPS (D) – Demonstration of historical data export from SCADA to database

By implementing these solutions for integrating UPS with SCADA, glass manufacturing facilities can enhance operational performance, ensure reliable power supply to critical equipment, and minimize downtime during the glass tempering process. This comprehensive approach offers industry professionals and researchers valuable insights to optimize production processes and improve overall efficiency in glass manufacturing facilities [10].

2. CONCLUSIONS

In conclusion, the challenges faced by tempering and bending furnaces in the glass manufacturing industry, particularly concerning power disruptions, underscore the critical need for reliable power supply solutions. Power outages can lead to various issues such as glass adhesion to conveyor components, uneven cooling of ceramic rods, and data loss in control systems, all of which can result in downtime, product wastage, and operational inefficiencies. The integration of an Uninterruptible Power Supply (UPS) with a Supervisory Control and Data Acquisition (SCADA) system emerges as a consolidated and definitive solution to address these challenges effectively. By ensuring continuous power supply during fluctuations and enabling real-time monitoring and control of the tempering furnace, manufacturers can safeguard production processes, minimize downtime, and optimize energy consumption.

Moving forward, it is imperative for manufacturers in the glass industry to consider the implementation of UPS-SCADA integrated systems to enhance operational resilience and efficiency. This proactive approach not only protects the quality of glass products but also contributes to cost savings and improved overall productivity [10]. As the industry continues to evolve, leveraging advanced technologies like UPS and SCADA will be instrumental in meeting the demands for reliable and sustainable glass manufacturing processes. By embracing these solutions and best practices, manufacturers can stay ahead of challenges and drive innovation in the production of architectural and automotive glass products.

3. ACKNOWLEDGMENT

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Trademarks: A Comparative Analysis of Unauthorized Use in Iran, South Korea, and China

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Abstract

Trademarks, a well-established and defining phenomenon in the realm of commerce and business, fall under the umbrella of intellectual property rights and serve a variety of functions. This legal construct, employed to distinguish between the goods, products, and services of individuals by identifying their producer and source, encompasses a diverse range of types based on various criteria. Trademark registration grants the holder exclusive rights, including the prohibition of unauthorized use by others. Consequently, one instance of infringement of trademark rights is the unauthorized use of another's registered trademark. This criminal act, which can manifest in various forms, is subject to specific conditions and elements for its realization. Moreover, the legislatures of Iran, South Korea, and China have also provided protection for trademark holders against infringing acts, establishing corresponding legal remedies. This research delves into the conditions for the realization and legal consequences of this offense, examining the judicial practices and relevant laws of Iran, South Korea, and China. Finally, it offers several strategies for preventing such infringements.

Keywords: Trademark, Registration Offenses, Trademark Registration, Unauthorized Use of Trademarks

1. Introduction

Trademarks play a crucial role in the success and development of businesses. They provide a unique identity to products, goods, and services, distinguishing them from competitors and serving as a marketing tool to attract consumers. Additionally, trademarks guide consumers and buyers in selecting products that meet their criteria, such as quality and origin. Moreover, trademarks foster trust and credibility, enabling consumers to purchase their desired products without expending excessive time and resources. Therefore, the trademark system aims to strike a balance between the rights of producers and consumers.

Infringement of trademarks, particularly unauthorized use of another's trademark, disrupts this balance. Therefore, understanding the elements, conditions, and methods of infringement, along with the relevant laws and remedies available in the country's legal system, is both beneficial and essential. The research methodology employed in this study is based on library research and consultation with credible sources. The study aims to introduce the concept and function of trademarks, examine the infringement of trademark rights in the form of unauthorized use of another's trademark from various perspectives, and conduct a comparative analysis with the legal systems of South Korea and China to provide valuable insights for the readers.

2. Definition of Trademark and Its Necessity

Trademarks, which fall under the umbrella of intellectual property rights, are long-established and defining phenomena in the realm of commerce and business. This legal construct, employed to distinguish between the goods, products, and services of individuals, emphasizes the primary characteristic of "distinctiveness" in its various definitions.

The Iranian legislator, in line with this concept, has provided a definition of trademarks in Article 30 of the Law on Registration of Inventions, Industrial Designs, and Trademarks, approved in 1386 (2007). This definition aligns with the definition in international documents such as the TRIPS Agreement and the definition provided by the World Intellectual Property Organization (WIPO).

According to Clause (a) of the aforementioned article, a trademark is defined as "any visible sign that can distinguish the goods or services of natural or legal persons." These signs help companies differentiate themselves from their competitors and gain recognition. Additionally, by informing consumers about the quality of the product, they can enhance customer credibility and trust, creating a competitive advantage for these companies.

Moreover, a trademark can protect companies' valuable intellectual property assets. Upon registration, the registrant acquires the exclusive right to use the trademark and the right to prohibit unauthorized use (imitation and counterfeiting) of the trademark. [1]

3. Types and Functions of Trademarks

Trademarks, as marks that must possess the characteristics of ownership, non-misleadingness, distinctiveness, and compliance with public order and good morals, can be classified into various types based on different criteria.

From the standpoint of the subject matter of the activity, there are commercial, industrial, and service trademarks. Based on the legal definition provided, two types can be inferred: service trademarks and trademarks in the strict sense. In terms of visibility, there are visual, auditory, and olfactory trademarks. Based on the owners and users of the mark, there are individual, collective, certification, endorsement, and common trademarks.

Trademarks can also be considered based on whether or not they are registered or registrable. According to the Law on Registration of Inventions, Industrial Designs, and Trademarks (Th.A.T.L.), trademarks that are prohibited from registration and are not registrable are excluded, leaving registrable trademarks. [1]

As previously mentioned, the most important function of a trademark is to identify the quality and origin of goods, which falls under the category of the control function. A trademark serves as a guide for consumers to distinguish between the quality of similar goods. Accordingly, trademarks can also play a marketing and advertising role by encouraging consumers. Due to their emotional and psychological connection with consumers, trademarks alone have the power to influence their behavior and even lead them to purchase a product simply because it bears a trademark, regardless of whether the mark indicates a specific origin or desired quality. Therefore, investment can also be considered among the functions of trademarks. [2]

4. Concept of Trademark Infringement

Given the benefits and importance of trademarks in the world of commerce and the flourishing of economic markets, legal protection for trademark holders against potential risks and misuse that threaten the interests of companies and businesses, as well as to prevent consumer confusion, is essential. On this basis, the Iranian legislator has also provided for the rights arising from the registration of trademarks in the Th.A.T.L. to be subject to various civil and criminal remedies.

Trademark infringement occurs when a trademark belonging to another is used without authorization in a manner that causes confusion or deception of consumers regarding the origin or supply of goods and services, or damages the reputation or distinctive character of the trademark belonging to another. [3] In this regard, the legislator refers to two general criminal behaviors in Clause (b) of Article 40 of the Th.A.T.L.: 1-Unauthorized use of another's trademark, and 2-Any act that habitually leads to an infringement of the rights arising from registration (the rights of the trademark owner). It is noteworthy that the first case is in a way a sub-case of the second behavior, since unauthorized use of another's trademark is essentially an infringement of the trademark owner's most important right, which is the right to use and exploit the trademark. [4] We will further examine the conditions and methods of trademark infringement and refer to the relevant legal provisions in the Iranian legal system, along with judicial practice.

5. Conditions for Trademark Infringement

In summary, the elements of trademark infringement are: the existence of a registered trademark, unauthorized use of the trademark, and the likelihood of confusion regarding the characteristics and quality of the goods or their origin. Based on judicial practice, the commercial nature (non-personal) of the use of the mark should also be considered as one of the conditions for infringement.

As for the existence of a valid trademark, it should be noted that despite the existence of a legal provision for the protection of unregistered trademarks, courts extensively protect trademarks that have not been registered with a competent authority, relying on the concepts of prior use, acquired rights, and unfair competition enshrined in the Paris Convention.

In addition, despite the lack of explicit mention by the legislator of the commercial nature of the use of the mark and only mentioning the unauthorized use of another's mark that causes consumer confusion in absolute terms, it should be said that in the Iranian legal system, as in some other systems, including the US legal system, "commercial use" of the mark (not any use) is a condition for infringement.

Finally, the essential element of infringement, namely the likelihood of confusion or deception of third parties, arises when the aforementioned use leads to the creation of a perception among consumers of a connection, endorsement, or support from the trademark owner for the infringer of the right. [5]

6.Methods of Trademark Infringement

Trademark infringement can occur in various ways, including:

- Use of the identical trademark: This involves using the exact trademark of another person without their authorization. This is the most straightforward and blatant form of infringement.
- Counterfeiting of a registered trademark: This involves imitating the trademark of another person to the point where consumers are likely to be confused about the origin or source of the goods or services. Counterfeiting often involves copying the trademark's design, packaging, or other elements.
- Use of a similar trademark: This involves using a trademark that is similar to the trademark of another person but not identical. If the similarity is likely to cause confusion among consumers, it may be considered infringement.
- Conflict between prior registration and registration of use: This arises when a trademark has been used in commerce for a significant period before it is registered, and the registration of a similar or identical trademark by another party could cause confusion among consumers.
- Use of a trademark in meta tags: This involves using a trademark in the meta tags of a website to improve the website's ranking in search engine results. This can be considered infringement if it is likely to cause consumers to believe that the website is affiliated with the trademark owner.

Explanation of the First Two Methods:

1. Use of the Identical Trademark

The unauthorized use of the identical trademark of another person is the most obvious and direct form of trademark infringement. When a person uses another's trademark without their permission, they are essentially representing their goods or services as if they are associated with the trademark owner. This can mislead consumers into believing that they are purchasing products or services from the trademark owner, even if they are not.

2. Counterfeiting of a Registered Trademark

Counterfeiting involves imitating a trademark to such a degree that consumers are likely to be confused about the origin or source of the goods or services. Counterfeiters often copy the trademark's design, packaging, or other elements to make their products appear as if they are genuine products of the trademark owner. This can damage the

reputation of the trademark owner and cause financial harm to consumers who are deceived into purchasing counterfeit products.

6.1. Using the same trademark

One of the obvious examples of violation of the trademark and its owner's rights occurs when someone uses the same registered trademark on other goods, products and services in such a way that the consumer thinks that this is the original product. Since the element of misleading is fully realized, the possibility of misleading and deceiving the consumer is assumed.

6.2. Forgery of registered trademark

If a person falsifies a trademark after it has been registered and harms the rights of its owner, he will be punished for forging the trademark. We also see Article 61 of the Criminal Code, in which the intent to defraud is not a condition. The important point is that forging a trademark is not necessarily the same as violating the rights of the trademark owner [3].

7. Legal Consequences and Remedies in the Iranian Legal System

The existence of general laws to protect and support intellectual property rights can motivate innovation and production. Given that trademarks are an important complement to economic and technological growth and development and have a significant impact on the competitiveness of companies in domestic and international markets, considering protections and remedies to safeguard the rights of their holders is of great importance. In this regard, we have witnessed various regulations in the field of protecting the rights of trademark holders and criminalizing trademark rights-infringing behaviors in the Iranian legal system.

In the case of using a trademark belonging to another person, which is mentioned in Article 40 of the Th.A.T.L. as one of the instances of infringement of the rights arising from trademark registration, according to Article 61 of the said law, a financial penalty of ten to fifty million Rials and 91 days to six months in prison or both are considered as remedies. However, this level of punishment cannot achieve preventive goals. In addition, sometimes the violated interests of the holder may not be commensurate with this amount of punishment, and therefore, the principle of proportionality of crime and punishment may be compromised. [6] [7]

In the Islamic Penal Code, we have two articles, 525 and 529, regarding the crime of forging or using a forged trademark. The punishment mentioned in Article 525 is heavier due to the importance of trademarks belonging to companies and other government institutions. Also, the crimes mentioned in these articles should be considered non-compromisable.

If the crimes in question are committed in the cyber environment and in the context of electronic transactions, there are articles in the 2009 Computer Crimes Law and the 2003 E-Commerce Law that provide various remedies and have considered criminal liability for these cases. [4]

It is noteworthy that the legislator has prohibited the definitive entry of "goods with a mark or name or trademark or other specifications on the goods themselves or on their packaging in order to deceive the buyer and consumer about the manufacturer or place of manufacture or properties or main characteristics of that goods" in Clause (r) of Article 122 of the Customs Law of 1390.

8. Trademarks in South Korea: Legal Framework and Enforcement

In today's competitive marketplace, trademarks play a crucial role in differentiating a company's products and services from those of its rivals. This is why the protection of trademarks is of paramount importance. In the South Korean legal system, the unauthorized use of another's trademark constitutes an infringement of intellectual property rights and can be subject to civil, criminal, and administrative penalties.

Relevant Laws:

1. Trademark Act: This Act establishes the primary framework for trademark protection in South Korea.
 - a. Registrable Subject Matter: i. Names, marks, designs, symbols, or combinations thereof ii. Colors, if sufficient to distinguish goods or services iii. Sounds
 - b. Prohibitions on Trademark Registration: i. Deceptive marks ii. Marks contrary to public order or good morals iii. Marks similar to previously registered trademarks
2. Fair Competition Act: This Act safeguards fair competition in the market and prohibits deceptive use of trademarks.
 - a. Prohibited Acts: i. Using another's trademark to cause confusion among consumers ii. Falsely claiming affiliation with another company iii. Copying a competitor's trademark, packaging, or trade name
3. Civil Code: This Code outlines general concepts of property rights, including those pertaining to trademarks.
 - a. Rights of a Registered Trademark Owner: i. Exclusive use of the mark in South Korea ii. Preventing others from using the mark iii. Seeking damages for trademark infringement

Types of Trademark Infringement:

a. Direct Use: Unauthorized use of a third-party's registered trademark on similar goods or services.

Example: Using Nike's logo on unauthorized sports apparel

b. Indirect Use: Use of a third-party's registered trademark in a manner likely to cause confusion among consumers.

Example: Using a name similar to the registered trademark "Coca-Cola" for another beverage

c. Trademark Dilution: Repeated use of a mark similar to a third-party's registered trademark, weakening the distinctiveness of the mark.

Example: Using a logo resembling McDonald's logo for another restaurant

Remedies for Trademark Infringement:

a. Civil Remedies:

i. The registered trademark owner can claim damages from the infringer. ii. The infringer may be ordered to cease using the trademark and destroy counterfeit goods.

Example: Samsung can recover damages from an infringer using its trademark on counterfeit smartphones and demand they stop selling them.

b. Criminal Penalties:

In cases of willful trademark infringement, the infringer may face imprisonment or fines.

c. Administrative Sanctions:

The Korea Intellectual Property Office (KIPO) can impose fines on infringers or revoke their trademark registration.

Case Study: Samsung Electronics v. Apple

In this high-profile case, Samsung Electronics was accused of infringing several of Apple's registered trademarks, including "iPhone" and "iPad." Apple alleged that Samsung had copied the design and features of its products in its Galaxy smartphones and tablets.

The South Korean court ultimately ruled in favor of Apple, ordering Samsung to pay damages of 1 billion Korean won (equivalent to \$840 million USD). The court also mandated Samsung to halt sales of certain Galaxy smartphone models in South Korea.

This case stands as one of the most significant trademark infringement cases in South Korean history, with far-reaching implications for the country's technology industry. It also underscores South Korea's commitment to protecting intellectual property rights.

9. Use of Others' Legal Marks in the Chinese Legal System

In the modern world of commerce, trademarks serve as the visual identity of a company and play a crucial role in differentiating its products and services from those of its competitors. This is why the protection of trademarks is of paramount importance. In the Chinese legal system, the unauthorized use of another's trademark constitutes an infringement of intellectual property rights and can have severe consequences for the infringer.

The Trademark Law, the Anti-Unfair Competition Law, and the Civil Code of China provide the necessary legal framework for trademark protection. Under these laws, the unauthorized use of a third-party's registered trademark, whether direct, indirect, or dilutive, is considered trademark infringement.

Upon proof of trademark infringement, the owner of the registered trademark can take legal action to enforce their rights. Various penalties are available for trademark infringement, including compensation, injunctions against further use of the mark, and the destruction of counterfeit goods. Additionally, criminal penalties such as imprisonment and fines, as well as administrative sanctions such as fines and revocation of trademark registration, may be imposed.

In 2020, New Balance, a well-known global brand of athletic footwear and apparel, was ordered to pay a \$1.5 million fine for misleading advertising in China. This case garnered significant attention due to China's stringent advertising regulations and the brand's popularity in the country.

In its Chinese advertising, New Balance had claimed that its sneakers incorporated a specific technology that could significantly enhance one's athletic performance. However, after investigating these claims, the China Administration for Market Regulation (CAMR) determined them to be unsubstantiated and misleading. The CAMR further stated that New Balance did not employ this particular technology in any of its sneakers sold in China.

As a result of this ruling, New Balance was ordered to pay a \$1.5 million fine to the Chinese government. Additionally, the company was compelled to remove its misleading advertisements from both online and offline platforms.

This case highlights the Chinese government's serious stance against misleading advertising and its willingness to penalize companies that violate the country's advertising regulations. It also serves as a warning to foreign companies operating in China to adhere to truthfulness and accuracy in their advertising and refrain from making unsubstantiated claims.

10. Conclusion

As mentioned, trademarks, as a well-established legal institution, play an effective role in the prosperity and sustainability of the economic market and businesses. Therefore, recognizing trademark infringement behaviors and considering legal protections and regulations to combat and prevent them is noteworthy. Based on the conditions, methods, and remedies discussed regarding the most important instance of such behaviors, unauthorized use of another's trademark, it can be said that despite the protection of trademarks according to the Th.A.T.L. being subject to their registration with the competent authority, considering the judicial practice, it can be claimed that the Iranian legal system, and specifically the aforementioned law, also protects unregistered trademarks. However, trademark registration by the holder remains the first step to prevent unauthorized use by others, as registration grants the registrant the exclusive legal right to use that trademark in the market.

The dispersion of legal regulations related to the enforcement of unauthorized use of another's trademark shows that Iran does not have uniform regulations, and in the absence of adherence to jurisprudential and legal principles, the applicable law cannot be discerned.

Considering the aforementioned and the role that trademarks play in economic development through protecting intellectual property, creating a competitive advantage, valuation and marketing, preventing consumer confusion, and facilitating trade, the following proposals are made based on the research findings:

1. The practice of courts in protecting unregistered trademarks, despite the lack of explicit legal provisions, which has sometimes even led to the annulment of another registered trademark [5], should be reformed and brought into line with a legal approach; because this practice discourages businesses and companies that spend money to register trademarks, while there is a possibility of its annulment by filing a lawsuit by the holder of an unregistered trademark. This can lead to a lack of motivation for trademark registration and create greater challenges in protecting industrial property rights, and specifically trademark rights.
2. The ground should be prepared for the increased use of the legal institution mentioned in Article 44 of the Th.A.T.L., which is the license agreement for the exploitation of trademark registration or application, and incentives should be created in this regard.
3. With the increasing emergence and entry of artificial intelligence technology in all areas, measures should be taken to control the impact of this phenomenon in the field of trademark infringement. For example, artificial intelligence may offer counterfeit or trademark-infringing products in a list of goods and products provided to guide consumers in making a better choice, which can mislead consumers. [2] Therefore, in this case, it should be determined who is responsible for the infringement.
4. Artificial intelligence tools can be used to analyze large volumes of data, including images, text, and videos, to identify trademark infringement. These tools can help us identify subtle and complex infringements that may not be detectable by humans. In addition, they can be made available to the public for similarity searching and monitoring infringement of the rights of other owners.

It seems that in order to achieve the aforementioned goals, it is undeniable to utilize modern tools and update laws in light of the requirements of the new world. Therefore, it is appropriate for the research centers of the Parliament and the government to become active in this regard and find solutions using the capacity of university elites.

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Legal guarantees in construction and review of construction contracts and property rights in construction projects

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ABSTRACT

Construction contracts are documents that determine the rights and responsibilities of individuals in the construction process. While it is true that construction contracts are agreements between two or more parties for providing services in exchange for a specified amount, these agreements can sometimes become so complex that they pose challenges for the contracting parties. This research aims to examine legal guarantees in construction, analyze construction contracts, and explore property rights in construction projects using a descriptive-analytical method based on library resources. According to the research findings, various reconstruction contracts fall under the category of contractor agreements within the field of construction. These types of contracts are legal documents that must be signed by the parties after preparation. It is essential to exercise due diligence during contract drafting, as an improperly executed contract can significantly impact the entire reconstruction project. Reconstruction contracts for buildings are typically established between contractors and employers, necessitating that both parties possess the necessary knowledge regarding the specifics of such contracts.

Keywords: Guarantees, Contract, Construction, Property Rights, Research

1.INTRODUCTION

There may be various legal and contractual guarantees regarding the fulfillment of contractual obligations, which in some materials may not be necessary for the legal guarantee to work. In this situation, contractual guarantees in many cases can help the contractor to fulfill a contractual obligation. In this case, some of the contractual guarantees of the auditor relate to the time of performance of the commitment and part of the cases to the timing of the sale or the services provided[1]. It should be noted that there is essentially an aggregate between the contractual guarantees at the time of performance of the commitment, with the explanation that the guarantee of non-fulfillment of the obligation may not only be accompanied in some cases by the requirement of an accompanying commitment but also by the legal nature of such a guaranteed cumulative obligation relating to the delay in execution of the agreement and other contractual safeguards, but it is assumed that the Guarantee of cumulability does not simultaneously guarantee the proper performance of obligations. Also, given the present definitions of warranty-related guarantees, the guarantee commitment appears to be more conceptual, wider and comprehensive than the guaranteed commitment. This is because the commitment to guarantee first includes the ownership of the goods, as well as their quality and functionality, while guarantee primarily means guarantee and in some cases guarantee of the works of the seller[2]. In view of the importance of intellectual property rights and their preservation in contractual relations, the Parties, in their efforts to preserve the rights and confidential information of the other Party, have endeavored to protect these rights and information in different ways and not to violate them. A very important example of these contracts, which are not exempt from this, are contractual contracts in which each employer and contractor, in fulfilling their contractual obligations, may make use of the right to invention, technical knowledge, technology, trademarks or trademark created by him or a third party that keeps this valuable information and confidentiality important to their owners in the context of the confidential contract and makes commitments to each of the parties in this regard. Therefore, in order to reduce legal risks and risks, how to write and regulate a construction contract is very important. In terms of agreement, there is a substantial difference between the state contract contract and other contracts, including the private contract

contract, but the contract has a special nature and is distinct from the other legal contracts in civil law through the existence of form, terms and conditions as well as the characteristics and elements associated with it. The special nature which originates from the state description of this agreement and the particular effects that govern public rights. A disruptive effect that leads to preferences on the one hand for executive mechanisms, at the different stages of contract formulation and implementation. The philosophy is to create such a visionary nature for government contracts, in order to preserve the public interest of society. For this purpose, the governing bodies have established special regulations for the contracting industry. These terms, on the one hand, serve the interests of the community, and on the other hand, are a powerful tool for controlling contractors so that in the event of a contractor's breach of its commitments, the government or the employer can implement the common interest with the fastest and strongest guarantees. With the same approach, the constituent nature of the contract is more of an obligation to the contractors. The obligations provided for in various laws and regulations including the General Terms and Conditions of the Agreement, the Government Transaction Guarantee Act and the Convention recognize the jurisdiction of the Contracting Parties and provide different guarantees for the Contractor. These terms and characteristics of the contract have led to the fact that in addition to forming a specific nature for the contracting of a government contract, distinctive effects also arise from these characteristics and related claims that differ from other civil contracts. The effects and consequences that if the discussion of public rights or the interests of society were not accepted, we would have had to know this agreement is basically a void agreement and contrary to the principles governing contracts in general[3]. In the event of non-compliance with the aforementioned rights and their violation by each of the parties, this leads to disputes and legal claims, increasing the financial burden and delaying the completion of the project[4]. Moody's and Qi (1402) conducted a study entitled "Analysis of contractual guarantees from the perspective of economic rights" in which the study examined the economic and legal analysis of contractual guarantee[2], explaining that contractual warranties are the most appropriate tool to deal with the failure of the counterparty to fulfil contractual obligations. A subject that focuses on economic analysis aspects such as rationality, preference-based tools, maximization of desirability, theory of games and technical performance and specialization differentiates the behavior of economic operators in the market environment. Isanello and Shane (1399) conducted a study entitled "The Approval of the Clause of Liability in Contracts"[5]. The liability guarantee clause refers to the types of liability clauses and the economic risk allocation tools used in particular in oil and gas contracts. From an economic point of view, the institution has a parity function and puts the burden of economic risk on a party that usually has a greater capacity to sustain losses. The concept of this institution in the Commonwealth system as well as in the field of international trade agreements can also be discussed in Iran. The Ministry of Public Affairs of the People's Republic of Iran and the Republic of Belarus(1395) conducted a study entitled "The Measure of Contractual Guarantees and How to Register and Conditions of Request of Guaranteed Letters in Iranian Law and FIDIC Model Contracts"[6]. In contracts to ensure the fulfillment of contractual commitments, guarantees are taken from the committee. Despite the reference to some general conditions governing the warranties, the nature and scope of these guarantees are not specified in domestic law and model contracts. The World of Refugees(1393) conducted a study entitled "The Measures, Consequences and Barriers of Legal and Executive Guarantees in Contractual Contracts" [7]. The origin of the difference between the guarantee agreement and the dispute of guarantee in the contractual agreement is the same fact that the personal guarantee contracts as the guarantor of the obligations of the debtor, but in guaranteeing in the contract, the contractor personally guarantees his actions and measures against the employer, and only in some cases the employee can take the bank warranty from the contracting party, the bank also as the substitute of the member entering the agreement; in addition to the acceptance of bank warrants in international contracts, it is very common that in this study is summarized to guarantee bank letters and types of payment. The purpose of this research is to examine legal guarantees in construction and examination of construction contracts and ownership rights in construction projects, and so the question raised is how is the legal guarantee in the construction and review of construction contract and the ownership of construction projects? The assumption raised for this question is that in the Iranian legal system concerning construction and construction contracts existing laws and regulations have limits that need to be removed.

1.1 Contract

A contract or contract under Article 183 of the Civil Code means that one or more persons undertake to act and are accepted in respect of one or several other persons. As a result of a contract between the two parties, a new legal relationship is established and the parties must make obligations with respect to each other according to the subject of the contract. In a lifelong project, three main factors are involved:

Employers, designers and entrepreneurs who can have the units of project management or project management and construction management alongside them, as well as in the form or telephony of the above groups. These factors can be placed side by side in different modes and form different contractual methods by removing or integrating certain units together. In a very well-known perspective, the Golden Guidelines for Contracts contracts are described as follows:



Form number (1) Principles and lines of contract

In the contract of participation in construction, the landowner concludes a contract with the builder (real or legal person), in order to participate in the construction of a project of construction in the land that is being built. Contract of participation in construction, obligatory contract, corporate contribution, contractual-contractual, continuous, satisfactory, mixed and in some cases where a party to the contract is the government, the suspension administration, the bank is the current contract and in order to form this contract, the parties, like all the contracts, make obligations to each other that, after examination, may bring the content of the contract closer to one of the specific contracts specified in the civil law such as fraud, lawyer or civil company, or even in other cases removed from the scope of certain contracts and subject to Article 10 of the Civil Law[8].

In this Agreement, in addition to the rights and obligations that the original contracting parties have to each other, if one of the contractual parties has an action to pre-sale the building, the secondary contracting party, which may, as the case may be, establish the representative of one or more of the original parties to the contract, also has rights and responsibilities, and if the establishment of the initial contractual entities has a transaction in relation to the building being established, will also create rights and liabilities on the basis of the provisions of the contract for each of the originating parties, their establishments and a third party. The contract of participation in construction, like other contracts, may be terminated and the reason for its termination depending on the will of the parties to the contract and the contractual and legal terms and conditions may be a termination, dissolution or dissolution, each of which has its own specific executive guarantee, the most important effect of which can be known as compensation for the damages incurred[9].

2.1 Construction contracts and their types

There are different types of construction contracts. Determining the appropriate project contract helps owners, contractors and suppliers to control the risk of the project and to determine the scope of legal and contractual activities as far as possible. The importance of contracting construction contracts is so high that many companies are currently operating in the contracting sector[10].

3.1 Distribution of types of construction contracts

Construction contracts can be divided according to different criteria. The following are some of the most important criteria for the distribution of types of construction contracts. 4 Techniques of Distribution of Construction Contracts Distribution by method. From a financial point of view. Types of contracts based on how the message is delivered to the subject of the project. The types of contracts shall be examined in accordance with the manner in which insurance is secured in the continuation of each of these criteria and types of agreements[11].

4.1 Types of construction contracts

The types of construction contracts are divided into 5 categories. Paying attention to these categories and the characteristics of each will help improve the contract and its management. Regulating construction contracts based on construction laws and regulations will result in separation of tasks, improving the quality of buildings, facilitating project management and thereby increasing customer satisfaction.

1.4.1 Secure Construction Contract

Single-term or self-executing contracts, also known as security contracts are one of the most common types of construction contracts in the country. In the construction contract, the employer, in addition to funding the project, is responsible for all phases from design to implementation. In fact, in these types of contracts, which are mostly used in short-lived projects such as building, repairing and renovating a home, the entire responsibility for the project execution lies with the employer. It should also be noted that these contracts do not include contracts or contracts with foreign companies[12].

2.4.1 Construction contracts for two

The use of two types of construction contracts is considered, including ordinary and temporary methods in the implementation of construction projects. This type of contract is more organized than the one-off contract. In fact, a bilateral construction contract provides the possibility for an employer to use a contractor to facilitate the execution of their project. In this type of contract, all design and construction services are carried out by the contractor and the employer has more control and management roles. Construction contracts are two types of contracts, sometimes known as design and construction contracts and are divided into two general categories[13].

1.2.4.1 Design and Construction Contract

In the design and construction contract, the responsibility for all operations related to the implementation of the project such as design, design and implementation services is assigned to the contractor. In fact, the employer, after completing the design through a contract or direct contract, entrusts the design and execution of the project to the contractor, which improves the speed of project execution.

In addition to the complexity of selecting contractors that leads to reduced competition and increased prices, transferring a major part of the work to a contractor may lead to failure to meet expectations and increase risk for the employer[14].

2.2.4.1 Engineering, Architecture and Construction

EPC (Engineering, Procurement, Construction) is a type of two-stage construction contract. This type of contract, as it can be understood by its name, is divided into three segments: design and engineering, procurement and construction[15].

This method creates restrictions for the employer and all project activities are under contract. This feature makes the employer not involved in heavy managerial and executive responsibilities.

3.4.1 Three-party construction contracts

The three-fold construction contract is one of the most important and common types of construction contracts. In lifetime contracts, three members, the employer, the contractor and the counselor constitute contractual members. The process of this type of contract is in such a way that after the completion of the project design by the employer, the project is submitted to the contractor as a draft agreement. The most important advantages of the construction contract are three methods described below:

Possibility of using specialized companies and with experience in all phases of the project
 Reduce bureaucracy and accelerate work.

B. Conducting projects and creating and developing a new generation of contractors

Gold Opportunity for Specialized Competition and Creating Economic Savings in the Implementation of Projects

Also, the most important disadvantages of the three types of construction contract can be described as follows:

Not responsible for the project.

Complexity of creating coordination between the contractor and the design consultant company

C. Possibility of lengthy start of work due to delay in the design consultancy.

D. Creating an inefficient plan and spending a lot of time and money on repairing and rectification[16].

4.4.1 Four-party construction contracts

The fourth type of construction contract is a four-fold construction contract. The other name of the four-fold construction contract is the Executive Management Contract. In this type of contract, unlike a three-fold construction contract, the employer uses a foreign company to manage and control the project and coordinate between design and construction. Given the scope of the fourth factor activity, this type of contract can be enforced in different ways. For example, the use of the fourth factor in the entire project or in its executive part creates a new type of four-factor construction contract[17].

5.4.1 Construction, Use and Transfer Contract

Construction, exploitation and transfer contracts are more used in the implementation of infrastructure projects. In this type of contract, the construction and exploitation of the project is initially submitted to a company outside the group (usually private) and after a certain period of project is transferred to the employer for exploitation. These types of contracts have several different types, depending on the workflow, including construction, operation, transfer or (BOT) and construction, lease, transfer (BRT) contracts, which are very common.

5.1 The theory of compensatory justice regarding the price adjustment clause in contractual contracts in Iranian law

Based on the definition we mentioned at the beginning of the discussion, we can say that the basis of the price adjustment clause in contractual contracts is as a measure and mechanism to maintain the economic balance considered by the parties until the conclusion of the contract, to establish and uphold justice in this type of contracts and to create balance and balance between variables until the end of the project. But the question that arises is whether the duty to maintain and maintain this balance in the treaty lies solely with the parties, or is the legislature and the government also involved and monitored in this matter? Since the existence and acceptance of the amended clause in the general terms of the contract depends solely on its foreseeability or non-prevention, and its manner, scope and quality does not depend on the common will of the parties, and the Government in this context declares its own monitoring and intervention by declaring the indicators for the calculation of the adjustment price of the agreement, it cannot be subject to the theory of compensatory justice in absolute and unconditional terms[17]. On the other hand, today contracts have taken on a social face, and the preservation and safeguarding of individual interests and freedoms is not merely an obligation, and no government can limit its duty to the organization of individual liberties and to the observance of the natural laws of supply and demand, but also to the public interests of public order, national security,

minimum welfare, minimum health and minimum education[18]. But again, not to mean that the existence of the individual and respect for human personality and desires are forgotten, therefore the theory of compensatory justice can no longer be fully accepted and must be modified and asserted to the balance between the theories of equal justice and distributive justice[19]. According to this theory, the financial balance is established in the contract exclusively by the parties to the contract and without any intervention and supervision from the state, and this is because, in the case of government contracts, the employer and guarantor of capital, the government, the interests and social interests of the contract are placed and monitored, and the government exercises its own supervision and sovereignty on all sides. On the other hand, in Iranian law, based on the theory of justice, some credibility principles such as legal benefits and the pre-seizure rule were established in order to prevent distortions in the rights of the traders, in such a case when the goods are fixed and are lost before the delivery, the only way is to protect the damaged rights (the traders) and restore the balance lost at the time of conclusion of the contract - so that the customer uses the intention and intention of the price to reach the price, while after payment of the fee, the price is lost prior to the delivery - the breach is the contract, or when the contract clause or the default clause is the result of breach, the contract is only the way to return the balance to the contract and if the clause of default is the prejudice to the transaction or contract[20] and the These legal principles, according to the theory of justice, are compensatory measures to compensate for the loss of balance at the time of contract conclusion. However, there are some cases where the application of compensatory justice and compensatory compensation implies that the contract is amended or administered rather than dismantled or terminated, given that the principle is on the maintenance of contracts. For example, when unforeseeable events such as a sudden rise in the dollar rate of contract execution make it difficult, this is the contract-modification theory that helps to establish compensatory justice[21].

6.1 Analysis of construction contract.

As stated above, national building regulations are the only technical reference and guiding principles in the assessment of the quality of design, calculation, execution, operation and maintenance of buildings. In accordance with Article 7 of the Orthodox Practice of 1384 annexed to the second consideration of the same Regulations, all executive operations of the building shall be carried out exclusively by the building engineering offices or legal entities or construction entities, or the holders of the authority for the design and construction of buildings which are in the field of execution, according to the case, have a permit or butterfly employment of the Ministry of Housing and Urbanization as entity, pursuant to the general conditions of the contract and the conditions contained in the special conditions and the same entities referred to in Chapter 7 of this Practice and the public duties and responsibilities as described in Articles 8, 11, 10, 9, this Set of Practices and on the basis of the Chartered Plans and all documents included in the Agreement concluded with Therefore, having regard to the fact that these general conditions are drawn up for contracts of non-performance and in order to safeguard the rights and interests of the employer, buyers, beneficiaries, builders and national wealth, and the observance of its specificity in all contracts concluded between the employee and the employers and the building is mandatory for the analysis of the construction contract implementation should be taken into account these conditions. It should therefore be said that the construction contract is a service contract in which the service provider as an employee and the service recipient as an employer conclude a contract which has special conditions and thus also implies special obligations and powers that are not previous in other contracts.

7.1 Legal matters and construction contracts

Construction contracts typically include items such as payment terms, timing, obligations of the parties, fines and damages, terms of withdrawal and termination, execution obligations, use of interests and equipment, insurance, warranties and guarantees, dispute resolution and arbitration. Legal issues may also include matters such as the rights and obligations of the parties, intellectual and physical property rights, responsibilities, dispute resolution and arbitration. These cases may vary depending on the type of contract and the specific conditions of each project. which is fully explained. The purpose of this article is also legal matters and construction contracts.

8.1 Importance of Contracts in the Construction Industry

In general, contractual agreements are of great importance in the construction industry and must be prepared and implemented with sufficient care and knowledge to a proper balance between the rights and obligations of the parties and to prevent further differences[1].

9.1 Legal issues related to contracts.

Legal issues related to contractual contracts in the construction industry include the following:

Determining the rights and obligations of the parties: Contractual agreements should precisely specify the right and obligation of the Owner and the Contractor, including timing, fees, standards and technical specifications, the provision of materials and equipment, payment conditions and other related matters.

Security and Insurance Conditions: Contractual contracts should specify the security conditions related to the performance of the work as well as the cases related to insurance in order to protect the safety of employees and the project owner.

Dispute Resolution Methods: Contractual contracts should include specific methods for resolving disputes between the parties, including appealing to a court or using arbitration or mediation.

Financing: Contractual agreements should specify terms relating to payments, fines and project financing in order to ensure the proper implementation of the project.

Changes in contract: Conditions related to changes in contract should also be taken into account in order to follow the relevant process appropriately if changes in project execution are required.

10.1 Dispute Resolution in Contracts.

In contractual contracts, dispute resolution practices are very important so that in the event of disputes between the parties, these disputes are resolved civilly and without the need to go to courts. Some common methods for resolving disputes in contractual contracts include:

Arbitration: In this manner, the parties agree to refer disputes to the arbitrator or to an arbitration board. The arbitral decision is binding on the parties and is considered as a quick and efficient way to resolve disputes.

Mediation: In this way, the parties try to reach an agreement with the presence of a mediator. The mediator plays an active role in facilitating negotiations, but the final decision is with the parties.

If the arbitration or mediation proceedings do not result in a desirable result, the parties may appeal to the court and refer their disputes to a court[22].

11.1 issues related to guarantees and payments.

Questions related to guarantees and payments in contractual contracts are of great importance in the construction industry. We will give a brief explanation on this subject:

1.11.1 Guaranteed

Implementation Guarantee: The project owner may ask the contractor to provide a guarantee for the proper and timely execution of the project. This guarantee is usually provided in the form of a cash amount or a bank guarantee.

Quality Assurance: Guarantees for the quality of the work and the use of quality materials may be specified in contractual contracts to ensure the correct execution and compliance with standards.

2.11.1 The payments.

Payment time: In contractual contracts, the payment time for the contractor is specified. This period may include initial payments, intermediate payments and final payments.

Conditions of payment: Conditions relating to payments are specified including percentage of work progress, terms of delivery of materials and equipment, and terms of payment of fines or rewards.

Penalties and withdrawals: If the contractor fails to fulfill its commitments at the time of the project. Provisions relating to penalties and repeats may apply in the contract.

12.1 Ensuring fulfillment of commitments in the contract.

Ensuring the fulfillment of commitments is a letter of guarantee that the contractor gives to the employer to bring the confidence that he will fulfill his commitments until the time of the project's operation and temporary delivery. The guarantee of fulfillment of the commitments must be issued by the bank that the bank is accepted and the employer accepts. This definition clarifies that guaranteeing the fulfillment of commitments is actually a tool that the employer can use to ensure the implementation of the subject of the contract by the contractor. In addition, if the contractor fails to comply with its contractual obligations, the employer may obtain the guarantee amount from the issuing bank to prevent damage[23].

13.1 Delivery time to guarantee fulfillment of commitments in the contract

The contract attorney explains, the delivery time is the guarantee of fulfillment of commitments by the contractor to the employer at the time of conclusion of the contract. Although the employer may declare the conditions of the warranty in advance and the acceptance of the bank, the time of delivery is at the time when the contract is concluded, not before.

14.1 Ensuring the fulfillment of obligations under the general agreement.

Ensuring the fulfilment of the obligations is provided for in the general terms of the contract and if the contract is a function of the general conditions of the agreement, the enforcement of its obligations and conditions shall be guaranteed in accordance with Article 34 of the General Conditions. Under this article, the contractor must provide the guarantee of fulfillment of the commitments to the employer at the time of signing the contract. The contract attorney describes the most important conditions for ensuring the fulfilment of the obligations under Article 34 as follows:

The warranty letter must be in accordance with the sample that the employer has agreed to supplement the documents before concluding the contract.

The guarantee of fulfillment of commitments must be issued by the employer's accepted bank.

The guarantee of fulfillment of obligations must be valid for one month after the date of provisional delivery of the contract subject.

The guarantee of fulfillment of commitments must be equal to 5 percent of the initial contract amount.

15.1 A private contract

In private contracts, unlike government contracts there is no obligation to comply with the general terms of the contract. On this basis, the parties to the contract may set different terms regarding the general conditions, including the subject of guaranteeing the fulfilment of obligations, from the general terms of the contract in the contract, which makes the importance of having knowledge and information in the field of the kinds of safeguards, including ensuring the fulfillment of the commitment, more precise[24].

16.1 Guarantee of non-extension of term

The contractual attorney explains, in accordance with Article 34 of the general conditions of the contract, if the contractor does not extend the guarantee of fulfillment of the commitment until 15 days before the expiration of the validity period of the warranty or does not provide the reasons for the extension, the employer has the right to receive the amount of guarantee from the bank and keep the face of it, instead of the security letter, as a certificate with him. The important thing to keep in mind is that the employer should not think that the amount of revenue belongs unconditionally to him. This is only a fixed amount, and if the contractor does not fulfill its obligations, it will be possible for the employer to withdraw it[25].

17.1 Liberalization guarantees fulfillment of commitments in the contract

The guarantee of fulfillment of the obligations under Article 34 of the General Conditions of the original contract must be released within one month after the provisional delivery. However, if the contractor's debt is greater than a specific amount, this guarantee shall be released after the settlement of the account provided for in Article 52. Also, if the employer refuses to guarantee the fulfillment of his obligations, the contractor must file the complaint for the fulfillment of the obligations in the courts of law[26].

18.1 Types of Contracts in Construction

Similarly, as the owner of a contract of participation in construction, you must be prepared to provide guarantees to fulfill your obligations in the contract. Naturally, any commitment is made by providing a strong and reliable guarantee, and if you want to guarantee the manufacturer's commitments, you must also be able to give them guarantees to get more confidence from performing your duties in the contract. "Executive guarantees of the contract of participation in construction" shall mean:

1.18.1 Ensuring good work

Your contract of participation in construction must be arranged in such a way that all stages of the construction operation and the quality of the performance of the lifetime operation and other matters related to the contracted construction are precisely defined and the criteria for evaluating the manufacturer's quality of work are considered. In fact, the performance of the work must be accurately evaluable in the light of the contract so that in the event of the manufacturer's failure to fulfill his obligations in the contract, you can measure the degree of rejection or reversal of

the producer from performing his duties and the amount of low construction quality in relation to what is stipulated in the agreement. In this case, guaranteeing the good performance of the manufacturer will make sense. Based on the guarantee of good work, the manufacturer undertakes to perform his work well and with the quality specified in the contract, and in case of defects in the work, must pay the damage to the owner. This is the name of [27]. The defect margin is actually the proportion of the healthy and faultless performance that is stipulated in the contract and the producer's stable and defective execution. In the guarantee of good work, as the owner, you make predictions that allow the manufacturer as a guarantor to correct its defects in the project and complete the building with the required quality in the contract or to pay for its defect and failure to a certain extent in the warranty. In such a guarantee, the damage that the manufacturer is liable to pay is not the loss of failure to perform the obligation, but the damage caused by a defect in the performance of the work or the defect is calculated in accordance with Article 27 of the Civil Code[28].

But in order to be able to work with a good manufacturer's guarantee, what conditions do you need to meet? The guarantee of good performance in participation in construction must meet the following conditions: the guarantee must be given before the damage occurs and only the type and amount of damage is determined. The guarantor is the person who may suffer from the benefit obtained from the performance of his commitment to the other side the damage value and suitability of the guarantee must be determined entirely with the guarantee's consent and guarantee the type of commitments that the manufacturer guarantees in favour of the good, must be at the time of conclusion of the contract of participation in the particular construction you may have heard about the contracts related to Article 34 of the Law of Registration. Contract of participation in the construction of these contracts does not involve. According to Article 34 of the Registration Law, damage must have occurred in order to be able to sign the contract. But in the contractual guarantees of participation in the construction, you must consider the remedy before any damage occurs, and the appropriate safeguards must be determined[29].

2.18.1 Delay in performance of commitment

In the execution guarantee of the contract of participation in the construction of the type of good performance guarantee, if the defect is of a small or non-qualitative nature, the manufacturer must remedy the existing defects. Lack of sufficient interest in building is an example of these few shortcomings. If the manufacturer fails to remedy these defects, you as the owner can remedy the related defects with court permission and we can recover the cost of removing those defects from the manufacturers' assets.

3.18.1 Guaranteed Investment

Now the question is whether you have to agree with the manufacturer on what amount as a guarantee or guarantee you have at your disposal, that we will compensate for the corresponding amount of damages in the event of failure to fully fulfill the obligations on the part of the producer. Articles 35 and 36 of the General Conditions of the Agreement state that:

In order to ensure the proper fulfillment of the contractual obligations, the contractor must, at the time of signing the contract, provide the employer with a warranty equal to 5% of the initial amount of the relevant contract. The remuneration of each contractor shall be equal to 10 percent as a guarantee of good performance and shall be kept on the account of the employer[30].

4.18.1 Guarantee for delayed performance in the contract of participation in construction

Another problem that you may anticipate during the execution of the contract of participation in construction and put measures and guarantees for it in the contract is the manufacturer's delay in fulfilling its commitments. The manufacturer is obliged to carry out all construction-related operations at the time stipulated in the contract and is responsible in case of delay in fulfilling its obligations. To ensure that you, as the owner of the contract participating in the construction, do not suffer from manufacturer delays, you charge the manufacturer to pay you an amount of

damages or liabilities for each day or month of delay in fulfilling its obligations. In such a case, by receiving a warranty letter from the manufacturer, it was possible to receive damages caused by his delays. Please note that the liability of the manufacturer's guarantee against delay in fulfilling its obligations must be settled with the agreement of the parties to the contract before the damage caused by the failure to fulfil these obligations occurs. If you do not guarantee the manufacturer at the time of each of the stages of construction before you fail to fulfil the obligations of the maker, you will not be able to obtain the guarantee from the producer after the damage caused by this[31].

5.18.1 Investment Guarantee in Construction Contract

Another type of participation contract guarantee is the capital guarantee, which in this type of guarantee the owner guarantees the manufacturer in respect of the land that is available for construction and due to the non-compliance of manufacturer with his obligations in the contract. This guarantee is taken in relation to the progressive ownership of the contract and the commitment of the manufacturer. The guarantee of capital in the contract of participation in construction must be taken in such a way that the capital and damages incurred to you as a result of the manufacturer's failure to undertake an obligation shall be payable from the place of guarantee in question[32].

19.1 Results

In the general terms of the contract, two types of guarantees are placed on condition in the contract of employment, one provided for in Article 34 under the title "Garantiing the fulfillment of obligations" and the other in Article 35 under the name "Garanting the good performance of work". The damages and difficulties of guarantees in contracts include damages arising from the law of guarantee in the general terms of the agreement, including legal inconsistencies in general terms and conditions that cause discrimination between the extent of the options and responsibilities of each of the contractual parties and the imbalance and balance of the rights of the parties in the event of delays, as well as imbalances in the availability and obtaining of warranties, guarantee fraud and fraud within the framework of Article 19 of the United Nations Convention, including other problems of warranty in contractual agreements. Given that the documentary validity is not applicable by nature to any of the specific contracts under Article 10 of the Civil Code, it is an independent contract that has the exclusive aspects of the individual and can retain all its effects and characteristics only in the form of Article 10. Having regard to the Law on the System of Engineering and Construction Control and its Executive Decree, as well as national construction regulations, the identification of the construction contract as a validator of certain contracts for engineering services, whose special rules are provided in the general conditions of the contract and any injury and legal modification of its elements will strengthen the position of this type of contract. It should be acknowledged that although the draft Law on the system of engineering and building control and national building regulations recognize only contracts for engineering services, the prediction of the general rules of service contracts in our country can be a valuable step that covers all new services and contracts that are used according to the needs of the day and with the technological advancement of human knowledge; so that no more space in the legal system of our country will prevail. Especially that the legal literature of our country is very poor in terms of ensuring pre-contractual obligations and obligations for contractors, and this is always due to the interpretation of the will of the parties and the resolution and settlement of contractual disputes. The provision of general rules in service contracts, in addition to the fact that it can derogate from this distinction, as stated, is consistent with the structure of our country's legal system and is not unprecedented, as well as with recognized legal institutions in the world.

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A Comparative Study of the Social and Political Base of Groups and Parties in the Formation of the Constitutional Movement and the Islamic Revolution of Iran

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ABSTRACT

The constitutional movement and the Islamic revolution of Iran are two decisive historical moments in contemporary Iran, both of which sought fundamental political and social developments. In both periods, different groups and parties emerged with different social and political bases and played a role in the process of developments. The current research aims at a comparative study of the social and political base of groups and parties in these two periods, which begins with an overview of the history of the constitutional movement and the Islamic revolution, and then analyzes the social structure and the role of political parties and groups in both periods. A special emphasis has been placed on the role of clerics, intellectuals, merchants and marketers and different social strata in the formation and advancement of these two movements. With this explanation, the mentioned article aims to answer the question, what is the commonality between the social and political structure and the parties of the constitutional movement and the Islamic revolution? To answer this question, the hypothesis of this article will be as follows: "The parties and socio-political classes that played a role in the formation of the constitutional movement are different from the social and political structure of the formation of the Islamic Revolution of Iran. " By presenting a comprehensive analysis, this article helps to better understand the role of parties and social groups in Iran's political developments and can be used as a source for comparative studies in the fields of political sociology and contemporary history of Iran.

Key words: constitutional movement, Islamic revolution, social base, political structure, groups and parties.

1. INTRODUCTION

Throughout history, moments of social transformation are often characterized by the emergence of powerful movements and revolutions that change the social, political and cultural structure of nations. In this, groups and parties have an important and extensive role. Social groups can exert their influence in political processes through the formation of alliances, movements and various organizations. Members of social groups form strong connections and alliances through their ideological, cultural and social ties. These associations can directly or indirectly affect government policies and political decisions. Socio-political parties are also representatives of society's opinions and formulate their plans and policies based on these opinions and positions. They can present political, social and cultural programs, promote their ideas and values, educate and support their members. Also, social parties and groups can play an important role in creating social and political changes by using various advertising tools and be important institutions in political decision-making processes. The country of Iran is not exempted from this rule in contemporary history, and with the beginning of the constitutional movement and the Islamic revolution, it brought critical moments, both of which sought deep political and social changes in the country's structure. In both movements, different groups and parties with different social and political bases were present and each of them played an important role in their formation and advancement.

The constitutional movement is an important turning point in the history of Iran, which started in order to limit the powers of the king in the royal system of Iran and institutionalize fundamental rights such as individual freedom, judicial justice and the rule of law and led to the transformation of the political system of Iran from an absolute monarchy to a constitutional monarchy. This movement was strengthened by various social and political groups including intellectuals, businessmen, religious figures and the urban middle class. On the other hand, the Islamic Revolution of Iran was a great political and social transformation that was won with the support of various groups including religious scholars, students, intellectuals, workers and deprived sections of the society and under the leadership of Imam Khomeini (RA). This research is important because by examining the social bases and political parties, it helped to better understand the nature and process of the constitutional movement and the Islamic revolution of Iran, to examine their intellectual and social demands and the process of the effective groups and parties in these two. Shows the time.

This research is a theoretical research; in which the method of collecting information is in the form of a library. The tool for collecting information in this research is extracting historical documents, books and articles.

2. Intellectual and Social Origins of Constitutional Movement and Islamic Revolution

"Constitutional Movement" and "Islamic Revolution" are two important intellectual and political events in our contemporary history, which can be mentioned as two important and influential developments in the contemporary history of Iran in the field of fighting tyranny and dependence. Iran's constitutional movement and Islamic revolution both occurred in a situation where Iran was dominated by tyranny and colonialism. People were fed up with the corruption, inefficiency and injustice of the government and wanted political and social changes. The political incompetence of the Qajar dynasty and the conclusion of colonial agreements such as Golestan, Turkmenchai, economic privileges and imposition of capitulation, tyranny and self-centeredness, corruption ruling the court, the influence of foreigners in the political structure and the weakness and submission of the government to them, the majority of religious people and He made scholars pessimistic towards the government and fueled public hatred against Qajar.

In the constitutional movement that occurred at the end of the 19th century and the beginning of the 20th century, the religious forces wanted justice and the formation of an institution called Adalatkhan to defend their rights against the oppression of the king and courtiers, including Ayatollah Tabatabai, Ayatollah Tabatabai, Allah Behbahani and Sheikh Fazlullah Nouri pointed out. Iranian intellectuals wanted to establish the constitution, constitutionalism and justice. They also sought to develop education, freedom of speech and press, and people's participation in political affairs. On the other hand, the Islamic revolution that occurred in the late 1970s was influenced by the ideology of Islamism. The leaders of the revolution believed that the imperial government was corrupt and dependent on the West, and an Islamic government should replace it. They wanted to establish social justice, implement the rules of Islam and national independence.

3. Groups and Parties in Iran's Constitutional Movement and Islamic Revolution

A wider range of groups and parties with different intellectual and political tendencies were present in the formation of Iran's constitutional movement and Islamic revolution, and we mention some of the most important ones.

a. Constitutional movement

1- Clergymen:

One of the most important and effective groups in the constitutional movement were the clerics. On the eve of the constitutional movement, for the first time, the Shia clergy raised the issue of political jurisprudence, political thought and the formation of a government system in Shia Islam, and they started designing the foundations of politics and government in Islam. In the absence of the Imam of the time (AS) and the failure to achieve an ideal government in his absence, they sought to find a legitimate government model that fits the needs of the time[1].

Clergymen, as an influential group among the people, always participated in various ceremonies such as holding congregational prayers, mourning, holidays and other religious occasions and promoted the constitutional movement to the people because of the oppression of the sultans. It is also important to pay attention to the fact that the clerics, while having influence and social power, not only did not hinder the activities of other groups, but at different historical times, they formed alliances with other groups and cooperated with them[2].

Clergymen were important in several aspects during the constitutional period, which are: 1- Cultural field: increasing the awareness of the mass of people in line with inviolability; 2- Economic and social sphere: emphasis on the implementation of justice; 3- The field of domestic politics: "theorizing and redefining modern concepts such as law, state and nation and reforming the structure of the monarchy and colonial rule to constitutionalism with a legitimate flavor"; 4- The field of foreign policy: the struggle and non-interference of foreigners in the country's internal affairs. The hallmark of their activity is anti-colonialism, for example, we can mention the action of the late Sheikh Mullah Ali Keni in the Reuters case and the fatwa of the late Mirzai Shirazi regarding the ban on tobacco. During the constitutional movement, scholars and clerics were the manifestation of the people's religiosity, and even before the constitutional period, they did anti-colonial activities, such as the threat to the Russians by the late Akhund Khorasani to occupy Iran; Therefore, the role of clerics in the developments of the constitutional period has been to remove the tyranny of rulers, revive religion, remove domestic and foreign tyranny, etc[3].

2- Intellectuals:

The history of the formation of the intellectual movement in Iran goes back to the era of Fath Ali Shah Qajar and the reform era of Abbas Mirza before the constitutional movement[4]. In this period, according to the trips to the West, new ideas and trends spread and created a new middle class called intellectuals who were influenced by the European schools of thought that formed the intellectual current in Iran. In fact, the confrontation of Iranians with the West led to the formation of an intellectual movement. During the era of Feth Ali Shah Qajar, Iran's defeat in two wars with Russia created a kind of self-awareness among Iranians and caused them to feel Iran's backwardness against the West. At this time, Abbas Mirza sent students to England in order to make reforms in the country's structure, and later, during the prime ministership of Amir Kabir and Sepehsalar, reforms were made in various structures of the country. Therefore, the confrontation of the Iranians with the western civilization made them realize their instrumental and technological backwardness and demand the development and industrial progress of Europe. In the beginning, the main goal of the intellectuals was to form an organized army so that they could compensate for the past failures, and because of this, there were changes in the structure of the Iranian army. The expansion of relations between Iran and Europe caused new ideas and tendencies to enter Iran and influence the thinking of Iranian elites. The consequence of these influences is the spread of new concepts and ideas such as freedom, legalism, development and progress in Iranian society, and this caused the formation of a new middle class called intellectuals[3].

In the book *Iran between two revolutions*, Abrahamian says about the goals of the new intellectuals: "They wanted to establish and establish constitutionalism (to destroy the reactionary monarchy), secularism (to destroy the influence of conservative clerics) and nationalism (to dry the roots of imperialist exploitation). "[5] It is also important to note that the intellectuals demanded the implementation of reforms by the government, that is, they did not believe in the role of the mass of people, scholars and traditional systems, and their main demand was modernity without Iranian interference (instrumental modernity). The belief in this type of reforms and modernity was due to the fact that some of them were effective in the political and social structure of their time, for example, Mirza Malkam Khan sought to establish an orderly autocratic monarchy on the orders of Naseruddin Shah Qajar, but when he met with the then government Iran clashed over lottery concessions, published the newspaper *Qunun* in London and supported the constitutional government. The intellectual stream tried to imitate the West, but due to distance from the cultural foundations of the society, they created an identity crisis, or in other words, they demanded modernity without understanding the essence of Western modernity. Seyed Jamaluddin Asadabadi was one of the intellectual scholars of the Qajar period, who considered the most important problem of Islamic society to be internal and external tyranny.

In the letters he wrote to the scholars and mujtahids of Iran and Iraq, he mentioned the many privileges that the Shah had given to foreigners and called them to fight against the colonialists[3].

3- Traders and marketers:

Marketers are one of the social forces that political thinkers are interested in, who have a significant role in the process of political and social events in different societies[6]. In Iranian society, marketers did not make any effort to gain political power until they got acquainted with the West and modernism. On the other hand, the military force had given Eilat the opportunity to mobilize forces to take over the government, but Iran's confrontation with modernity caused a crisis in the political, social and cultural structure of the country. In addition, there was a conflict between marketers and intellectuals and the government, so familiarity of Iranians with the West made them enter the political field and try to gain power[7]. The low class consciousness of the bazaars made them unite with different unions, associations and organizations, and they tried to achieve their demands by squatting, closing the bazaar, and emigrating. In the Constitutional Decree (14 August 1285), Muzaffar al-Din Shah recognized the traditional middle class and its constitutive classes, i.e. marketers and clerics, and considered the formation of the National Council dependent on their presence in the parliament[8]. In the process of the constitutional movement, marketers played a revolutionary role in the constitutional victory and the formation of the first National Assembly due to their possession of economic capital, especially money and urban labor. They played a progressive and revolutionary role in the victory of the constitutional movement through financial support for the settlers in Abdul Azim Shrine, financial support for migration to Qom, as well as closing the bazaar and paying the costs of the sit-in at the British Embassy and mobilizing the labor force of the bazaar[9]. In fact, there are various guilds that exist in the market as an institutionalized and organized socio-economic network in the market, which helped to mobilize the masses in the protest movements of the constitutional movement[7].

Mehdi Malekzadeh writes about the social trust and credibility of the marketers with the revolutionaries and the influence of the support and social participation of the marketers in the formation of the constitutional movement: "The merchants formed an assembly with the cooperation of some famous freedom fighters and took some of the heads of the guilds with them. and in opposition to the government, they joined the leaders of the nation, it didn't take long for several reputable and trustworthy merchants, such as Haji Seyed Mohammad Saraf Alavi, Haji Mohammad Taqi Shahroudi, Haji Amin Al-Zarb, Haji Ali Shal Forosh, Moin Al-Tajar Bushehri, Haji Mohammad Taqi Bankdar and some others took the reins of affairs and an important center capable of revolution was formed, which became an important factor for obtaining constitutionalism in the future. "[10]

4- Parties:

There were no political parties in Iran before the constitution, and during the reign of Naser al-Din Shah, secret associations were formed. In fact, the main reason for the formation of these associations was the trips of ambassadors, officials and students to Europe, who, observing their governance style, demanded reform and improvement in the country [11].

On the eve of the constitutional victory, trade unions, local and political associations were formed, but in general, the party emerged during the period of the second parliament of the National Council. The essence of the existence of parties in a society is the culture and traditions of that society. A historical study shows that the ethnic structure of Iran was similar to a complex mosaic in which each piece has a different shape, size and color, so they were alien to issues such as political parties and working groups, and only during the Pahlavi period and the Islamic Republic did the tradition Tribals have been left out. Among the political groups and populations of Iran before the constitution, there were three currents of Maniwians, Mazdakians, and Zarvaniyeh, which can be considered as the initial seeds of political parties in Iran[12].

Nishat Association, Daneshvaran Association, Khaqan Association, Jamiat Bazarganan, Maarif Association, Women's Freedom Association, etc. were among the associations that performed some functions and roles of parties in the vacuum of parties before the emergence of political parties in the constitutional period[13].

b. Islamic revolution of Iran

1- Clergymen:

From the time of Imam Khomeini's protest against the state-provincial associations bill (1341 AH) until the victory of the Islamic Revolution (1357 AH), we have witnessed the formation of four types of tendencies by the clerics in Iran:

1- Revolutionary clerics: This group of clerics were against the monarchy and the king and wanted to establish an Islamic government. Considering the fundamentals of Islamic political thought, such as the unity of religion and politics, they considered involvement in political and social affairs to be a religious duty. In their opinion, Islam is a comprehensive and perfect religion, therefore, based on the principle of preserving Islam, they stood against the anti-Islamic policies of the Pahlavi regime. This trend was led by Imam Khomeini (RA)[14].

2- Court clerics and monarchists: this group supporting the king and the monarchy supported Muhammad Reza Pahlavi as the Shia king and they were fiercely at odds with the revolutionary clerics. Some of them were in the service of the country's intelligence and security organization[15]. Ayatollah Seyyed Kazem Shariatmadari was at the head of this movement. This tendency considers the existence of the monarchy and the king's rule as a refuge for Islam against the invasion of communism and considers the king as "Zal Allah".

3- Non-political clerics: At the head of this group was Ayatollah Azmi Khoei, the great authority in Najaf Ashraf. Although in theory they did not consider religion to be separate from politics, but in practice they studied and taught in seminaries, spiritual and moral issues and training students[14].

4- Obstinate and regressive clerics: this movement opposed any struggle against the king and somehow did not consider uprising during the absence of Imam Zaman (a.s.) as permissible. Thought trends in seminaries such as Qom and Højatiyeh Society can be included in this tendency[16].

Clergy played a long-standing reference and guiding role in Iran's political and social developments, and they were the only group that had the ability to mobilize the masses. This same role in the formation, advancement and victory of the Islamic Revolution of Iran emerged more prominently than before, hence the role of the clergy in the Islamic Revolution can be explained as follows:

1- Guiding and leading the revolution: unlike most of the contemporary taqlid authorities who were tolerant towards the Shah, Imam Khomeini (RA) entered into the struggle by mixing religion and politics, and other clerics followed his example and started the uprising in other cities. They led and led the people's struggles with a large presence on the scene, so for the first time the clergy participated widely in the struggle against the Shah's regime[17]. Proposing the theories of the unity of religion and politics, the theory of doing duty, the theory of prohibition of taqiyyah and the theory of victory of blood over sword by Imam Khomeini (RA) changed the position of seminaries and clerics and the Muslim community so that entering politics is considered as a duty. became. Also, the design and explanation of the theory of religious authority by Imam Khomeini (RA) dealt the final blow to the imperial political system[14]. Even though the leadership of the revolution brought heavy costs for the clerics, but because it was considered a political duty, the companions and assistants of the Imam faced arrest, imprisonment and torture, and Imam Khomeini (RA) never wavered and despaired. This came from the high degree of faith in divine help[16].

2- Explaining and promoting the school of revolution: ideologies are the main tools of political mobilization in revolutions. Marxism, nationalism and liberalism were among the ideologies that were promoted by some people during the revolution, but the Shia clergy, the school of Islam and Shiism were chosen as the ideology of the revolution and mobilized the masses with its help. The main ideologue of the revolution, Imam Khomeini (may Allah be pleased

with him) used the Ashura school to emphasize the fight against oppression and the arrogant and support the oppressed. The justice-seeking spirit of the clerics made the masses and strata of the people join them. Also, the world government plan of Hazrat Mahdi (AS) encouraged the masses of people to join the ranks of the revolutionaries[14].

3- Mobilization of the people: Certainly, any social group that is more familiar with the religious beliefs and feelings of the people can play a more important role in mobilizing the masses of the people. In Iran, during the Islamic Revolution, scholars and clerics played a key role in rousing the Muslim masses through holding speech sessions in the decades of Muharram and Safar and religious holidays in mosques[16]. Raising awareness, raising awareness and revealing about the objective disordered conditions of the society, training revolutionary forces and spreading revolutionary spirit, supporting and supporting the leader of the revolution, creating solidarity between opposing forces, optimal use of traditional media, etc. also show the influence and role of clerics. in the victory of the Islamic revolution.

Therefore, according to the chaotic and unfavorable conditions prevailing in the society during the Pahlavi regime, the militant Shia clerics led by Imam Khomeini (RA) were able to propose an alternative school to the imperial ideology, that is, the Islamic state, the acceptance of the leadership of the revolution, the training of revolutionary forces, etc. By taking advantage of the great organization of the clergy, they spread the revolutionary spirit among the mass of people and by mobilizing various strata of people and taking advantage of divine aid, they overthrow the imperial system [14].

2- Intellectuals:

During the time of Pahlavi II, there was no original intellectual movement in Iran, which means a movement without party and ideological affiliations that seeks reforms and cultural development of the society. Especially in the years after 1332 AH, due to the suffocation prevailing in the society, the closure of the critical press, censorship, etc., there was no suitable ground for the formation of intellectuals and intellectual work in Iran [18]. During the period of Muhammad Reza Pahlavi, because the intellectuals were influenced by the revolutionary atmosphere, they could not assume rational and reasoning leadership and followed popular sentiments[19]. It seems that the charismatic leadership of Imam Khomeini (RA) confined the intellectuals to the goals and demands of the traditionalists. Therefore, according to the prevailing conditions, the intellectuals accepted the leadership of the clerics. The lack of connection between the Iranian society during the time of the Shah and the Islamic characteristics of the revolution can be considered the most important reason for the confusion of intellectuals[18].

Between the years 1342 and 1357 AH, the third generation of intellectuals can be classified under three discourses of left intellectuals (Tudeh Party, People's Fedayee Guerrillas, the fighting group branched off from the People's Mojahedin Organization), liberal-nationalist (National Front parties and Writers' Union) and religious (Clergy, Islamic Coalition Party, People's Mojahedin Organization and Bazar). Left intellectuals, inspired by Marxist models and revolutionary activities in third world countries and the student revolts of the 1960s, Imam (RA) sought to change the existing conditions; The liberal-nationalist intellectuals had set the constitutional law as their standard and opposed the government as well. The main reason for the opposition of this group of intellectuals is the performance of SAVAK, the lack of political freedom, censorship and internal corruption, so they emphasized the indigenous identity and alienated the identity of the West in social and cultural fields, and finally, the religious intellectuals who in the form of Islam and the Shia religion, they examined social developments and considered non-compliance with religious orders to be the main problem of society.

1- Left intellectuals: Left intellectuals were influenced by Marxist ideas. According to this group of intellectuals, as long as the government is in the hands of the aristocracy, it is impossible for the people to achieve justice and freedom. Tudeh party is among the examples of left intellectuals and the works of people like Khalil Maleki, Ehsan Tabari, Bijan Jazni, etc. are eye-catching at this time. Among the characteristics of the leftist discourse can be considered the criticism of imperialism and the policies of the Shah's regime, adherence to dialectical materialism, emphasis on party

affiliation, acting within the ideological framework of the party, and believing in the possibility of creating local modernity based on national and socialist principles.

2- Nationalist-liberal intellectuals: The intellectuals in the first Pahlavi period came to the conclusion that the chaos after the failure of the constitutional movement should be resolved first and then the issue of freedom and liberalism should be addressed. Mohammad Mossadegh was against the transfer of the monarchy to Reza Khan and warned that the powerful king would violate the principles of the constitutional constitution. In the 40s and 50s, the intellectuals emphasized on the observance of the constitutional law so that the freedoms of the people would be preserved and stable. This group of intellectuals were active in the form of National Front parties, Writers' Union and some other cultural organizations. The liberal-nationalist discourse in confronting the western culture and solving the identity crisis adopted the approach of nativism. Nativeism means returning to native beliefs, customs and cultural values. This thinking can be seen in the works of Jalal Al Ahmad and Ehsan Naraghi. Among the characteristics of the liberal-nationalist discourse, we can also point out criticism of the West, especially in the human and moral dimension, efforts to return to the native identity, alienation of the government and the West, and the use of culture and literature fields such as universities for political activism.

3- Religious intellectuals: This group of intellectuals can be divided into two main categories: national-religious intellectuals and clerics. National-religious intellectuals have had academic education, including Dr. Ali Shariati and Engineer Mehdi Bazargan, and after the death of Ayatollah Boroujerdi, the activities of clerics such as Ayatollah Motahari and Imam Khomeini (RA) started.

By publishing the book *Kashf al-Asrar* (1323 AH), Imam Khomeini (RA) showed that he believed in the involvement of religion in the field of society's politics. He always emphasized the active role of religion in society and placing it at the center. After the death of Ayatollah Boroujerdi, some of the religious people became inclined towards Imam Khomeini (RA) and Motahari[20]. Motahari reaches an important conclusion about the responsibility of individuals in society: "The teachings of the Quran are completely based on the responsibility of the individual." Self and community responsibility. Enjoining what is good and forbidding what is evil is the order of individual rebellion against the corruption and criminality of society. The stories and anecdotes of the Qur'an often include the element of rebellion and rebellion against the environments and atmospheres of social corruption." [21] In front of those who considered their only duty to perform worship, expressing the social responsibility of individuals and their efforts to change the existing situation means a change in their attitude. Imam Khomeini's theory of religious authority was actually a logical conclusion of the opinions and arguments of many Shia scholars of the 19th century. From their point of view, in the absence of the Imam of the Age (AS), as during the time of the Prophet, scholars should form an Islamic state, and the realization of an Islamic state requires a new institution. Also, Imam Khomeini (RA) argued that the scholars are the only true interpreters of the Sharia, so the government should be left to the clerics, especially the jurists.

It seems that engineer Mehdi Bazargan emphasized the role of religion in material life matters and considered the autocratic government to be an obstacle to the country's progress and the cause of social instability. Dr. Ali Shariati emphasized on the responsibility of man (person) in the society. Seeing the problems of the society, he was the harbinger of returning to himself. For him, returning does not mean retrospect, but it means returning to the actual self existing in the society. In fact, he sought to find an identity to save the society from problems.

Belief in the social dimension of Islam, emphasizing the Islamic religious identity, theorizing the Islamic government (with the theory of religious authority) and resorting to religion to fight against tyranny and colonialism and Western culture are among the features of the discourse of religious intellectuals. The intellectuals in this period were from the middle and lower class of society and their audience was the expanding new middle class. Each of the intellectual movements had a central signifier, for example, "Islam" is the central signifier of the religious discourse, "identity and freedom" is the central signifier of the liberal-nationalist discourse, and "Marxism and Socialism" is considered the central signifier of the leftist discourse. It seems that all the intellectual discourses in Iran were playing an intellectual role due to their responsibility and commitment in the society, but the lack of a clear road map and

knowledge of the positions of the opposition group, and the lack of the element of reason and not having the right foresight, prevented They played an effective and efficient role[20]. Among these three groups, religious and leftist intellectuals contributed more to the reconstruction of the political system. Of course, it is also important to pay attention to this point that at first the leftist and liberal-nationalist intellectuals played a major role in Iran's political environment, but gradually religious intellectuals added to them and eventually played a more decisive role[18].

3- Traders and marketers:

During the second Pahlavi period, the presence of marketers in revolutionary actions had ups and downs, which can be briefly divided into four stages. In the first stage (mid-1330s to early 1340s AH), the role of Bazarians was in the form of scattered and incoherent critical actions, covering religious meetings and mosques. However, since the beginning of 1342 AH and with the establishment of the Islamic Coalition Committees with the opinion of Imam Khomeini (RA), their activities mainly included protest actions and cross-sectional actions. The assassination of Hasan Ali Mansour by the allied military branch and the execution and imprisonment of a number of leaders of this group caused the role of bazaarians to be played again under the cover of cultural, social and religious activities, partly with the cooperation of clerics inside Prisons were used to strengthen the beliefs of the fighters and another part was carried out outside the prison under the cover of cultural-educational activities. Finally, with the unity of the first class revolutionaries under the leadership of Imam Khomeini (RA) in 1356 AH, the activities of Bazarians took on a revolutionary aspect and in the form of structures such as "Tehran Militant Clergy Society", "Revolutionary Council" and "Committee of Strikes" until The victory of the Islamic Revolution continued.

The market is the most important axis of communication in cities, so for this reason, it is also considered the most important communication channel of cities. In addition to the presence of people and the flow of goods and capital in it, news and information reached the people through the markets, so the government sent some people as messengers to spread the news in the main market of the city and inform the people[22]. On the other hand, marketers themselves acted as a news transmission network. For example, when it was rumored in the city: "The shops are closed" or "The market is closed", people and even the uninformed knew that there was a protest going on. In fact, the market strike functioned like a news network in the era of lack of mass communication[23]. The Bazarians were organized through a relatively permanent religious system, which was organized around religious institutions and institutions (Shiaism, religious studies centers, mosques, etc.). The branches had a wide influence on the urban population[24]. For this reason, many analysts have considered Bazarians to be the backbone of the Islamic revolution, which, in contrast to the performance of the Pahlavi government, strengthened its communication networks, financial system, religious discussion and debate groups, and its own traditions of social cohesion and played a huge role in provided the financial and organizational resources of the revolution[25].

Despite the suffocating rule and the political and financial pressures of the government system, the traditional marketers relatively maintained their power and efficiency and had more organized social relations and class self-awareness than the new capitalists. Because the bazaars could not adapt themselves to the western culture, nor could they give up their religious and national culture, they did not take any religious obligations towards the government, and this caused the solidarity of this class with the clerics, who were with the interests The ruling class is in conflict. A group of the main reasons for the opposition of the bazaar institution and the traditional bazaars with the government apparatus and the new bourgeoisie and their all-round presence in the events of the Islamic Revolution can be stated as follows: First, the bazaars, like other traditional, religious and Shia sections of the society Iran was fanatical and reacted against the anti-Islamic actions of the government and the prevalence of Western beliefs. Second, the Bazarians had a deep connection with the clergy and like them, they considered the non-innocent government to be illegitimate. Describing the government as illegitimate and ideas such as making income halal in case of paying khums and zakat, caused the markets to avoid paying taxes to the government and only give khums and zakat to the clergy so that the purchase and sale of property would find a shari'a ruling. The third reason for the market to join the ranks of the revolutionary forces is the market's correct prediction of the course of economic reforms. The measures taken by Tehran Municipality for urban development and especially the construction of the highway through the middle of the

bazaar did not mean anything other than political and religious opposition to the bazaars. The fourth factor, which was actually the end of Bazarian's arguments towards the regime, was the regime's anti-inflationary policy after the economic crisis of 1345 to 1356 AH. The anti-inflation policy, which was completely unfair, not only did not solve the economic crisis, but also caused the market to become more hostile to the regime[26].

4- Parties:

Among the most important parties active in the achievement of the Islamic Revolution are the Islamic Coalition Board, the National Front of Iran, the Freedom Movement, and in the Marxist tendency, the Tudeh Party and the Mojahedin-e Khalq.

1- Islamic Coalition Board: This committee was formed by resorting to secret meetings under the supervision of Imam Khomeini (RA) in the two sections of the Clergy Council and the Central Committee, but later, with the addition of a military branch, it tried to conduct its activities in the light of the planned struggle based on the ideals and goals of Imam Khomeini (RA)[27]. The duty of the members of this community in the early days of the formation of the Marjayat and Imam movement was to publish and distribute their announcements, organize the demonstrations and guide the issues related to the movements in the city of Tehran [28]. According to the statements of Asadollah Badamchian, Mutalfeh group, which consisted of the three groups of the Amin al-Dawlah Mosque, the Sheikh Ali Mosque Committee, and the Isfahani group, initially acted and operated without cooperating with each other, contrary to Pahlavi plans, but by introducing them to each other by Imam Khomeini (RA) provided the basis for their union and one of the most important actions of this alliance was opposition to the bill of provincial and provincial associations, the assassination of Hasan Ali Mansur, and opposition to the Shah's referendum[29].

2- National Front: It is one of the political groups that was founded in 1328 AH by Dr. Mossadegh and some nationalists and emphasized on peaceful activities throughout his life. This front believed that the king should become a constitutional king at his own discretion; A belief that was considered impossible by Mohammad Reza Pahlavi at that time. They after a period of political stagnation and the dissolution of the third parliament, they announced their existence once again in the open political space in 1356 AH along with fourteen other parties and communities. This open space gave them the opportunity to send an open message to three people (Karim Sanjabi, Shapour Bakhtiar and Dariush Forohar) and criticize the performance of the Pahlavi regime. They started a new round of their activity in December 1356 AH as a parliamentary struggle against the Pahlavi regime, but this method of struggle was not appropriate for the time because the people basically wanted the complete overthrow of the Pahlavi regime. Therefore, their leader, aware of this, met with Imam Khomeini (RA) in Paris and by signing a statement, he publicly expressed his support with the religious forces. But this meeting led to the division of the National Front, so that a part of them cooperated with the regime, and the other part of them, led by Dr. Sanjabi, continued to accompany the revolutionary forces in the form of opposition groups, marches and strikes until the victory of the Islamic Revolution [30].

Ayawzi writes about this: "The National Front, on the eve of the victory of the Islamic Revolution, assessed the situation as suitable for being at the head of power, so one of the leaders of this front, namely Shapour Bakhtiar, became the prime minister of the imperial government. Accepting this position in the final moments of the Shah's rule was opposed by Imam Khomeini (RA) and the revolutionary people of Iran and caused scandal and exposure of this front in the eyes of the people. To the extent that many of them inevitably fled to the West." [27]

3- Freedom Movement: In 1340 AH, the Freedom Movement, which had distanced itself from the national front due to its religious affiliations, declared its existence as a "Muslim, Iranian, subject to the Constitution and Mosadqe" organization in the speech of Mehdi Bazargan[31]. According to Maithami's memoirs, this movement was welcomed by religious students and the freedom movement penetrated the academic atmosphere. A long time later, the student leaders of the movement formed the student committee of the freedom movement in the form of five-person group meetings. In these meetings, the members discussed the various materials they had studied or analyzed the issued notices[32]. During different eras, the freedom movement tried to have a deep relationship with the clergy and declared their support for clerics such as the late Taleghani, Zanjani and others, and the leaders of this movement praised the

leadership of Imam (RA) and opposed the six bills and the White Revolution. but with the difference that their form of struggle was more based on nationalism and law-oriented and was different from the way of struggle against Imam Khomeini (RA). They emphasized the principle that the monarchy should be the responsibility of the king and not the government, and they wanted the government of the king to depend on the constitution[33]. Also, from the interaction that the Azadi movement had with the Pahlavi regime, it can be concluded that although this movement believed in fighting against Pahlavi, it never looked at overthrowing the Shah's regime, and their struggle had a reform aspect[34]. However, with the rise of people's protests and struggles, this movement, like other groups and parties, was forced to accompany them[27].

4- People's Mojahedin Organization: This organization, which can be considered as the continuation of Marxists in Iran, was founded by three students who separated from the freedom movement in 1344 AH. Their first action after deciding to form this organization was to formulate an ideology. The People's Mojahedin considered Iran's situation to be a reflection of global trends and believed that the Pahlavi government was nothing other than securing the interests of imperialist countries. One of their solutions to overcome the disadvantages that occurred in the past struggles and did not find fruit was to shape the revolutionary organization so that the struggle would have the color of an art and a profession for victory. Among the reasons that the People's Mojahedin paid attention to for the revolution was the community's despair over the victory over the Pahlavi regime and its overthrow after the Khordad 15 uprising. According to them, in order to eliminate this despair, an armed struggle should be started to break down the barrier of despair and hopelessness. This interpretation and theory was a factor for the People's Mojahedin to use armed measures as the best method of opposition[35]. In this regard, it was decided that at the beginning of the 2,500-year celebrations, the main electricity pylons would be destroyed and exploded, which, of course, were identified and suppressed by the Shah's intelligence forces; Nine of them were sentenced to death, and Masoud Rajavi and Bahman Bazardani were sentenced to life imprisonment [36]. The most important event of this organization is the issue of changing their ideology, which caused the emergence of various divisions in the body of the members, one of these divisions, in the name of the People's Mojahedin of Iran, against the left-wing deviant movement after the release of Masoud Rajavi from prison in He became his leader in 1357 AH, and by paying attention to the weakness and inefficiency of other branches, he was able to introduce himself as the main representative of the organization [37]. Their intellectual foundations were to some extent indicative of the fact that the organization does not believe in clergy and authority, and in their thoughts, the community of clergy was considered a tool to achieve its goal. One of the examples and manifestations of the non-belief of the People's Mujahideen in Islam? was the fact that they did not believe in the practical treatise and considered it the product and result of feudalism. Also, they had their own special opinion in dealing with religious issues [27]. Imam Khomeini's position against the organization was also non-cooperation, companionship and alliance with them, but due to the requirements of the time and the priority of the mission of the Islamic system to confront the Shah, he refused to take any action to scandal and also publicly deal with them due to the lack of deviation of the path of the revolution from his main priority[38].

5- Tudeh party: Tudeh party considered itself to be the continuation of the communist path. This party was prevented from revealing its beliefs either in 1310 AH due to the law prohibiting the formation of communal parties or in the years leading up to the Islamic Revolution due to being rejected by scholars and the masses. The Tudeh Party's view of the Pahlavi regime was such that it considered the Pahlavi government to be in favor of the capitalist and imperialist system and fought against this system based on its communist school. The purpose of this party during the second Pahlavi period was to create a socialist society, a national and democratic government, so that power would be transferred from one person to the national and democratic strata, i.e. workers, peasants, etc[35]. During the Islamic Revolution, the Tudeh party tried to negate the Islamic Republic and distribute its communist views in the society by changing the slogan "Independence, Freedom, Islamic Republic" and turning it into "Independence, Freedom, Social Justice". People's adherence to Islamic culture and the small number of members of this party caused their failure[27]. However, on the eve of the victory of the Islamic Revolution, the Tudeh party witnessed the height of the revolution without considering an efficient plan, and in the meantime, by creating some strikes in oil centers and also by organizing demonstrations, it tried to coordinate with the currents of the revolution. In fact, it should be said that these

strikes happened as a result of Imam Khomeini's (RA) speeches and messages, and less attention was paid to Tudeh Party's actions[39].

4. The View of Imam Khomeini (Ra):

Hazrat Imam Khomeini (RA) is the leader and founder of the Islamic Republic of Iran, and a brief examination of his thoughts and behavior regarding constitutionalism and the Islamic Revolution will be fruitful. From the perspective of the Imam (RA), the first factor that caused deviation in the constitution was the attempt of foreigners to break the clergy and the united ranks of the nation: "When you read the history of the constitution, you will see that in the constitution and after it first went ahead, some hands came and He divided all Iranian people into two classes. Not Iran, only, among the great clerics of Najaf, one group is pro-constitutional, the other is anti-constitutional. The clergy spoke from the pulpit of a group against the constitution, one group spoke against tyranny, if there were two brothers in each house, for example, in many places, one brother agreed with the constitution, and the other was authoritarian. In response to the removal of the clergy, the Imam (RA) says: "The clergy were completely removed from intervention and with insidious plots and poisonous propaganda inspired by the West, carried out by the intellectuals and the East, built the parliament in the eyes of clerics and religious people in such a way that interference in elections was considered from great sins and turning to oppression. the clergy were taken off the stage altogether and isolated."

He further summarizes about constitutionalism as follows: "In the constitutionalism movement, these scholars were at the head, and the principle of constitutionalism basically started in Najaf by the hands of the scholars and in Iran by the hands of the scholars and progressed. This is the power that they wanted for the constitution to be realized and the constitution to be in place, But after it happened, it was not followed, the people remained aimless, the clerics also left, Everyone went to their own work. On the other hand, agents of foreign powers, especially at that time, England, were working to remove them from the stage, either through assassination or propaganda by speakers and writers and They tried to remove the clerics from interfering in politics and give it to those who can, and they did what they did, that is, the name was constitutional and the reality was tyranny."[40]

From the point of view of Imam Khomeini (RA), "Islamic government is neither autocratic nor absolute, but constitutional. Of course, it is not constitutional in the current conventional sense that laws are passed according to the votes of individuals and the majority, but constitutional in that the rulers are bound by a set of conditions in the implementation and administration that have been determined in the Holy Quran and the Sunnah of the Holy Prophet (PBUH), This is the main difference between the Islamic government and the monarchical and republican constitutional governments."[41] Imam Khomeini (RA) believes that cultural, social and political structures, which are part of the basic structures of society, had significant effects on the popular uprising and the victory of the Islamic Revolution.

1- Cultural structural causes: According to Imam (RA), culture is the biggest institution that either destroys the nation or brings it to the peak of greatness and power [42]. According to the Imam (RA), the most important and necessary feature for this huge and important institution is its independence. Therefore, he introduces the culture dependent on others as an unhealthy and parasitic culture. This is the same culture that was formed under the domination and invasion of foreigners and arrogant powers and is built with the plans of others and is imposed on a society or societies[43].

2- Social structural causes: According to the Imam (RA), there was no progress in the country's social situation in the years before the victory of the revolution. The class divide was rampant in the big cities and the majority of the rural population lived in poverty. The Imam (RA) was looking for reforms and considered one of the main reasons for poverty and deprivation to be the extravagance of the government, which, influenced by Western culture, had caused an increase in cabarets and gambling dens, and ultimately corruption among the country's youth. Cruelty and injustice and replacement of ancient Iranian culture instead of Islamic culture and de-Islamization by the Shah had created the conditions for public dissatisfaction. Imam (RA) considered Islam as the source of mobilizing people. According to the Imam (RA), the spiritual transformation that Islam brings about in different groups and strata, including clerics,

marketers, academics, employees and women, caused their mobilization and participation, which led to the victory of the Islamic Revolution. Also, according to Imam (RA), the formation of gatherings in mosques in the months of Muharram and Ramadan by religious leaders and clerics and informing the people and making them aware of the situation in the society led to the mobilization of different sections of the people who wanted to overthrow the Shah's regime.

3- Political structural causes: According to the Imam (RA), during the time of the Shah, the political structure of the country was autocratic and dictatorial and included oppression and corruption throughout the country. According to Imam (RA), Shah tried to weaken Islam, isolate clerics and promote the idea of separation of religion from politics by using The policy of de-Islamization. Also, the government ignored the people, and there was no understanding between the government and the nation [44]. One of the prominent characteristics of Imam Khomeini (RA) was his "resolute faith" and "irreducible belief". His spirit and decision-making had a direct and undeniable influence on the process of the Islamic Movement and the victory of the Islamic Revolution. Ayatollah Shahid Motahari described the leadership of Imam Khomeini (RA) in the Islamic Revolution as "prophet-like" and considered it to be the type of leadership of divine prophets. Imam Khomeini (RA) was able to awaken the feeling of seeking God and worshipping God, which is hidden in the nature of every person, and moved the masses of people in this direction. Hence, the attractive and prominent personality traits of the Imam (RA), although they were not without influence in placing him in the position of leadership and people turning to him, but they did not play the central and main role[45].

5. CONCLUSION

In the contemporary history of Iran, there have been many events, but without a doubt, the constitutional movement and the Islamic revolution of Iran are considered the most important events in contemporary history in the field of fighting against tyranny and dependency. The Islamic Revolution of Iran took place seventy-odd years after the constitutional movement. The findings of this research show that the social and political base of groups and parties in both movements was distinct. The social base of the constitutional movement basically consisted of urban elites, intellectuals and businessmen who sought to modernize Iran's society and politics. In contrast, the Islamic Revolution drew its support from a wider range of social classes, including peasants, workers, and religious leaders. Although a brief comparative study about the socio-political base of groups and parties of two important events, it will clarify the importance and position of the Islamic Revolution even more. Despite the similarities between the two great events of Iran's history, it can be boldly claimed that the social-political parties and classes that led to constitutionalism are completely different from the social and political structure that created the Islamic Revolution. There is a huge difference between the two:

1- One of the similarities of the clergy community in advancing its goal of overthrowing the government of its time was that in both periods, the clergy groups were able to make fundamental changes in the political and social structures of the country with the support of the people and by using their religious power. In the constitutional movement, the clergy, as one of the groups opposing the old regime and authoritarian rule, played an important role and position in creating the reform revolution and the establishment of the legal and constitutional government. Emphasizing the importance of citizenship rights and maintaining human rights, they promoted the principles of democracy and rule of law. But in the Islamic revolution, the clergy as a key and effective institution in leading and implementing the revolution against the imperial government and establishing the Islamic system in Iran had a more prominent function. Emphasizing Islamic principles and religious values, they led people towards the revolution to fight and create social and political changes. During the constitutional period, the clerics were divided into two groups, a group of them supported the foundations of the constitution, but another group, such as Ayatollah Naini and Sheikh Fazlullah Nouri, demanded constitutionalism by adding Sharia to it. This difference of opinion between these two groups is very similar to the four categories of clerics on the eve of the Islamic Revolution, which was mentioned earlier, but the difference between these two periods is that the clerics supporting legitimacy could not impose their intellectual foundations on the constitutionalists. which eventually led to the martyrdom of Sheikh Fazlullah Nouri, However, on the eve of the Islamic revolution, this group of clerics agreed with the interference of politics in religion and finally took the helm

of the revolution and were able to prevail over other parties and currents with their intellectual foundations and ideology and put it at the head of the movements. make a revolution Based on this, it can be said that in the constitutional movement, the clergy played a reformist and democratic role as one of the institutions opposed to authoritarian rule, while in the Islamic revolution, the clergy, as an institution emphasizing Islamic principles and religious values, played a role He organized and led the revolution.

2- The intellectuals in both eras accepted ideas from the intellectual currents in the West and the East and paid less attention to Iranian-Islamic ideology, but nevertheless, the intellectuals and the intellectual current in the constitutional era considered the mere imitation of the West and modernization as the main reason for getting out of the existing situation. They also knew about the path of identity crisis, while the intellectuals of the Pahlavi era, on the eve of the revolution, emphasized the native identity and dealt with the alienation of the western identity in social and cultural fields. Also, during these two periods, the intellectuals were facing problems such as few audiences and repression by the central government, and their activities were declared illegal. The intellectuals of the Qajar period could not establish effective communication with the people due to the limited means of communication with the people, the lack of a common language, and so on. For this reason, they formed an alliance with the clerics and marketers who had influence among the people and brought them to their side. They brought them together and through this they brought their desires and goals to the ears of the people. But in the Islamic revolution, due to the problems that existed for the intellectuals, they not only had no influence among the people, but also could not influence the marketers and the clerics, so the scope of the intellectuals' activities was very limited and the clerics carried out their plans and goals. The revolution dominated and intellectuals were placed under their umbrella. Another difference between the intellectuals of the constitutional era and the revolution was that the intellectuals of the constitutional era demanded the implementation of reforms by the government, that is, they did not believe in the role of the masses of the people, scholars and traditional systems, but some intellectuals on the eve of the revolution, especially the liberal-nationalist intellectuals, were with the government. They used to oppose and in the meantime they considered the people as the main role in opposing the government.

3- During the constitutional movement and the Islamic revolution, merchants and marketers supported the revolutionaries and organized protests, gatherings and demonstrations. Also, they used their social position and influence for propaganda and acted as messengers between different regions and factions, thus facilitating communication and coordination between the revolutionaries. In the constitutional movement, businessmen focused on citizenship rights and used traditional methods such as demonstrations and negotiations, and always emphasized their role in achieving the victory of this movement, but in the Islamic Revolution, they focused on Islamic ideology and anti-monarchy sentiments. Therefore, they had a deeper connection with the clerics and wanted to try to win the revolution with the leadership of the clerics, and they used more modern methods such as propaganda and public relations.

4- In both periods, political parties and associations played a decisive role in mobilizing people, spreading ideologies, and creating political pressure to achieve their goals. But they also had differences with each other and their influence on Iranian society and politics was very different. The constitutional movement was focused on the establishment of a constitutional monarchy and all political associations were unanimous in achieving it, while the Islamic revolution was focused on the establishment of an Islamic government, and although the political parties had differences in some intellectual and ideological matters, the role They were more active in organizing armed campaigns against the government. It is also important to note that unlike the political parties of the Islamic Revolution, which were organized, the activities of the constitutional political associations were secret, scattered and less organized.

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Investigating and analyzing the performance of industrial automation and (PLC)

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ABSTRACT

Before the advent of industrial automation, manufacturing plants consisted of separate departments that operated completely separately and communication was done by operators. This form of production has many problems and has many limitations. Industrial automation is equivalent to controlling and guiding a device in an automated industry. It was for the first time in 1913 that Ford company used industrial automation in one of its assembly production lines, and for this reason, Ford is considered to be the leader of this issue in the history of automation. With the passage of time, programmable controllers or in English abbreviations (PLCs) were used. In simple language, PLC is a device with logic programming capability that can feed data as input to the device, process on them and finally control or display outputs. Industrial automation can be used in extensive areas. Controllers are the heart of automation that changed industrial automation in 1968 with the advent of the PLC. Early PLCs were often used in automotive factories. Nowadays, wherever the controller needs, the traffic lights to the power plant are used because of the many PLC applications. One of the most positive PLC applications is the rehabilitation of patients who have lost their ability to move for some reason. After the various movements are specified and used by the dynamic simulation analysis, PLC is used. Then, with PLC planning, the robot is controlled.[1] With the advent of microprocessors, the control of different units of a factory or industrial unit, instead of being controlled separately, are controlled centrally by a small computer. In this case, all the control circuit systems, including contactors, relays, timers and other controlling components, do not change, but the sensors receive information from different points and process the information and issue the necessary command to the industrial unit.[9]

Keywords: PLC, HMI, SIEMENS, ABB plc, industrial automation

4. INTRODUCTION

The control part in any industrial system must give commands to the operators according to the current conditions, so in a machine or in general in an industrial process, the first part of a control cycle is the collection of information from the process. The collection of information in industrial processes is done using sensors. These sensors act as the eyes and ears of a control system. Today, in many industrial machines, the use of sensors is common to the extent that the automatic performance of a machine can be graded by the number of sensors in it. The presence of various sensors in the automation process is so important that no automatic process can be formed without sensors, so sensors are one of the integral components of industrial automation systems [2].

PLC stands for Programmable Logic Controller, which means programmable logic controllers. With the advancement of technology and the use of microprocessors, there were significant changes in control processes, one of these changes is the use of industrial automation science and PLC in the process of industrial processes. Today, in the global competition, an organization should think about the production of mass, diverse, superior quality products, cost reduction, and ultimately lower cost in order to survive. Therefore, industrial owners try to mechanize their production processes as much as possible. In addition to this diversity in products, it forces manufacturers to constantly change and evolve in production lines. Therefore, the flexibility of production lines should be one of the goals of every

successful organization. Today, in production lines, in order for the product to reach the consumer in the desired form, it is necessary to carry out a series of operations on the product consecutively and one after the other in order to reach the consumer in the highest quality, which is the responsibility of this operation, is PLC industrial automation.[9]

1.1 Features of industrial automation

1- Better control of production processes- 2- High speed and accuracy of operation- 3- Ability to read all types of inputs- 4- Ability to transmit commands to systems and output parts- 5- Possibilities of connecting to the network- 6- Very small dimensions- 7 - High response speed - 8 - Security, security and high flexibility - 9 - Networking PLCs and the possibility of managing them.

1.1.1 Comparison of plc with contactor relay circuit

1-Reducing the size of the command circuit-2-Reducing energy consumption-3-Reducing mechanical failures-4-Reducing troubleshooting time-5-80% less wiring-6-Easier circuit reading-7-High flexibility-8- Convert parts to digital-9-High speed-10-No electronic and audio noise-11-Precise performance-12-More reliability factor-13-More complex tasks-14 More i/o.

1.1.1.1 PLC

The characteristics of PLCs are programmable, controller and logical. Their expandability is both modular and compact, that is, if it is modular, it can be added or subtracted, and if it is compact, it cannot be changed. Components of PLCs are divided into 5 power supply categories: ROM, RAM, CPU. Their selection criteria depends on the type of project, processing power, available memory, number and types of timers, cost and number of I/O.

In automation systems, the main task of control is the responsibility of the PLC, which by receiving information through the input terminals, senses the state of the machine and provides a suitable response for the machine. The possibility of defining different modes for the input and output terminals of a PLC has made it possible to connect the PLC directly to other elements. In addition, PLC includes a central processing unit (CPU), which executes the desired control program. This controller is so powerful that it can control thousands of O/I in different analog or digital modes as well as thousands of timer counters. This has made it possible to control any system, from the control system of machines with several O/I that perform simple tasks such as repeating a small work cycle to very complex positioning and positioning systems. This system can control and use up to hundreds of timers at the same time without the need for wiring and peripheral parts and only by writing a few lines of the program [9].

5. History of control systems

The evolution of control systems can be divided into the following four stages

- 1-Pneumatic control systems
- 2 electronic control systems
- 3- Direct digital control systems
- 4- Decentralized control systems (DCS)

2.1 Pneumatic systems

Before the use of electrical signals to control devices in the industry, pneumatic tools were used. In this way, air supply with a standard pressure of 100 psi was connected to each field instrument, and the input signals of the control system as well as the controller's commands were transferred as pressure changes in the air lines between the instrument and the controller. The items required in pneumatic systems to establish communication include compressors, air lines, regulators, dryers, etc. The signal sent from the device in the controller produces the necessary command for the operator with the help of proportional controllers, PID, PI. In this regard, in the 1950s, the first pneumatic controllers were released to the market. Many refineries and chemical and petrochemical industries still use this type of systems. In terms of safety, pneumatic systems are suitable for flammable environments and are also very durable, but due to the low response speed, these equipments are not suitable for advanced controls. At the same time, control panels of this type occupy a large volume [3].

2.1.1 Electronic systems

In 1947, the Bell company was able to invent the integrated circuit and in the 1960s it was used in the construction of electronic control equipment. The volume occupied by these equipments is less than the pneumatic type, and therefore the electronic control panels are smaller, but on the other hand, it is more difficult to protect these systems. It is very important to prevent short circuits and sparks in these equipments. Another problem is the contamination of signals with noise, which should be prevented with necessary measures [3].

2.1.1.1 Digital control systems

In the early 1970s, the use of computers to control the process was experienced. In this type of control system, a computer controls the entire process. In case of computer failure, you can use another computer that works as standby [3].

2.1.1.1.1 Decentralized control systems

With the introduction of microprocessors and microcomputers to the market, the work that was in charge of a computer in a process was divided between microprocessors and microcomputers and led to the creation of a generation of control methods called DCS. DCS stands for Distributed Controller System, its purpose is to perform control operations in a decentralized manner. Contrary to the appearance of the DCS system, all the controllers are brought to the control room and it seems that the control is done centrally [3].

2.1.1.1.1.1 Difference between PLC and DCS architecture

PLC, in terms of vocabulary, does not bring to mind the concept of being centralized or not, but what is observed from its application in practice is mainly centralized control. (Fig. 1.)

The first PLCs were introduced around 1972 to replace contactor relay circuits, then by applying mathematical functions and the possibility of analyzing analog data and implementing closed loops in them, it quickly opened its place in the industry. A few years later, in 1975, the first DCSs came into existence. Honeywell company offering TDC2000 and Yokogawa company offering CENTUM are among the pioneers of DCS.(Fig.2.)

In DCSs, unlike PLCs, the control action is decentralized and separate controllers that are networked with each other are used to control the process. At the same time, these controllers are connected to the operating systems through the network and receive basic values from them and send process information to them. Therefore, a DCS system has independent processors, the task of controlling the process is divided between them. Each of these processors has the ability to control several closed loops.

Because of their independent applications, DCS and PLC have been used in parallel for years. Neither can fully play the role of the other and eliminate the other. [5]



Fig.1.

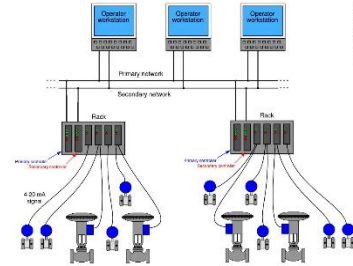


Fig.2.

2.1.1.1.1.1 Level of process equipment

At the lowest level of a DCS system are instrumentation, valves, actuators, and process equipment. In today's HAS system, the fieldbus is used to connect the field equipment to the controllers, while in the older systems, each equipment is directly connected to the input-output modules by two wires.[5]

2.1.1.1.1.1.1 Input parts

The intelligence of the automation system is more related to the ability of the PLC to read the signals sent from all types of inputs, manual, automatic and automatic sensors. Input parts such as start-stop buttons, switches, microswitches, photoelectric sensors, proximity, level sensor, thermocouple, 100PT and... PLC from these sensors to perform operations such as part detection on the conveyor belt carrying parts, color detection, liquid level detection inside The tank is used to know the mechanism of movement and the position of the object, to test the pressure of the tanks and many other things. The input signals are either digital or analog, in any case, PLC inputs can be set and used in different modes. [9]

2.1.1.1.1.1.1.1 Output parts

As you know, an automated system will not be complete without the ability to connect to output parts such as coil, motor, inverter, electric valve, heater, etc. The output parts show how the system works and are directly affected by the execution of the system control program. In the PLC outputs, there are also different modes for applying signals to the output elements [9].

2.1.1.1.1.1.1.1.1 Application of plc in open pit mines

PLC can be used for different purposes. For example, in construction stone mines, the process of controlling the tension of the diamond wire and deciding whether to pull or release the wire, in order to increase the cutting efficiency, can be fully automated by PLC. This process can reduce the consumption of cutting wire and make the stones more uniform.

Also, this system can monitor the degree of involvement of the cutting wire with the stone and the weight on the floor cutting wire, and before the cutting wire gets stuck, through an additional electric pulse, it causes the cutting wire to be released and thus the cutting wire stops. and inform the workers about the situation. [4]

6. Types of PLC production companies

1- ABB plc -2- Allen Bradley -3- Mitsubishi plc -4- Delta plc -5- Siemens plc -6- Omron plc -7- Hitachi plc -8- GE plc (General Electric) -9- Honeywell plc -10- Fatek plc -11- Schneider electric plc -12- Bosch Among all these companies, the best ones are Siemens, Allen Bradley, and ABB, with a global reputation and powerful software.

3.1 All kinds of Siemens PLCs

1- logo -2- S7,200 -3- S7,300 -4- Simatic CF -5- S7,300f -6- S7,300c -7- S7,400 -8- S7,400h -9- S7,400fh - 10- S7,1200 -11- S7,1500

3.1.1 Structure of PLCs

PLCs have a power supply (PS).

CPU

IM communication rack

SM (modular signals, digital and analog input and output)

FM (counters and location sensors, etc.)

CP (a communication bridge such as Ethernet- Profibus - Point to point).(Fig.3.)

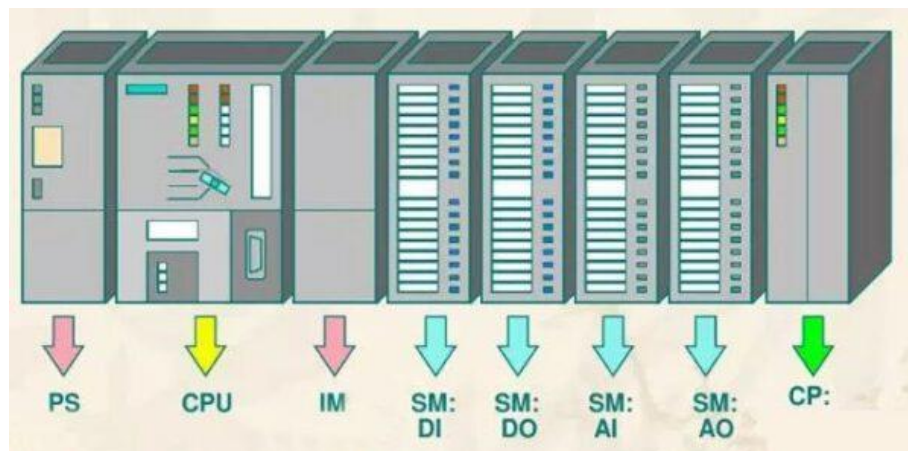


Fig.3.

3.1.1 HMI

With the development of industrial control systems, the tasks of operators are becoming more complex; Therefore, operators need more flexible and efficient control tools. To meet this need, HMI is a very useful tool.

HMI stands for Human Machine Interface (HMI) meaning the interface between human and machine. In fact, this equipment is an industrial hardware-software interface that provides the possibility of graphic communication between the user and industrial equipment or processes. Graphical communication is often done through a touch panel, tablet or industrial computer.

This interface is programmed and configured through its special software and provides the user with simulated images of process components and information related to their performance. [6](Fig.4.)



Fig.4.

3.1.1.1 Authentic HMI brands

A large number of companies in Europe, East Asia and America are active in the production of industrial automation equipment, among the common brands in Iran, the following can be mentioned:

- 1- Siemens
- 2- Delta
- 3- LS
- 4- FATEK
- 5- Schneider
- 6- ABB
- 7- Omron
- 8- Allen Bradley

Asian brands such as LS and Delta have enjoyed high popularity in the industry in recent years due to their more reasonable prices and easier access. However, leading hub brands such as Siemens, ABB and Schneider are still the first choice of design engineers due to their better quality and efficiency and higher reliability factor for sensitive industrial processes such as oil and gas and petrochemical industries. [6]

7. PLC programming:

PLC programming according to the IEC standard has the following programming:

- IL (Instruction List): It is a low level language.
- FBD (Function Block Diagram): Graphic and based on blocks.
- LD (Ladder Diagram): It is a ladder language that is very practical and easy to understand.
- SFC (Sequential Function Control): This language is based on the order of the algorithm.
- ST (Structured Text): The level of this language is high and similar to the C programming language, which has a complex algorithm.

An example of a simple logic circuit (AND) that the difference between the three languages LAD, FBD, ST in Siemens PLC can be seen in fig5.[1]

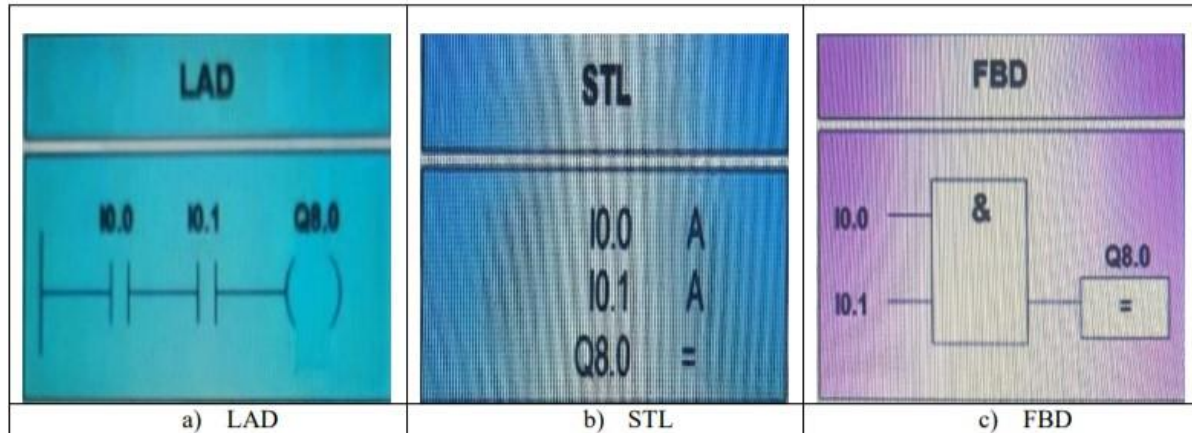


Fig5.

8. Application

In general, PLC is used in all industries such as plastic, oil, gas, petrochemical, etc.

- Chemical industries: Including: mixing systems, material combining devices
- Automotive industries: Automatic drilling operation, connection of parts, as well as testing of car parts and equipment, paint spraying systems, shaping the body with the help of automatic presses
- Machine industries: Packaging industries, wood industries, drilling systems
- Plastic industries: Melting and injection molding machines, air blowing and plastic production and analysis systems.
- Medical industries: Robots for rehabilitating various disabled organs of the patient [7-8].
- Energy conversion industries: Gas pressure boosting stations, power generation stations, water pump control, industrial air and water purification systems, gas purification and recycling systems.[1]

9. Results and discuddion

This is the industrial automation that changed the way of production of oil and petrochemical factories upon entering the industry. Industrial automation has made it possible to integrate and connect various factories and improve efficiency and quality. With these changes, processes are improved and more coordinated. Industrial automation improves the efficiency and quality of products, reduces costs and increases productivity in the production process. This technology aims to improve security and errors, and also creates a dynamic and advanced work environment. By using industrial automation, it is possible to save energy and workers, and by using a monitoring system, changes can be observed and controlled.

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Application of PMSM with dq Reference Frame in Electric Vehicles

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ABSTRACT

Permanent Magnet Synchronous Motors (PMSM) are increasingly popular in Electric vehicles (EVs) due to their high efficiency, compact size, and excellent control capabilities. This article examines the application of PMSM in electric vehicles, focusing on the use of the dq reference frame to enhance performance. We explore the theoretical background of dq transformation, its implementation in motor control, and the benefits it brings to electric vehicles. Case studies and simulation results demonstrate the effectiveness of this approach in improving the efficiency and responsiveness of electric vehicle propulsion systems.

Keywords: Permanent Magnet Synchronous Motors, Electric vehicles, Pole, Torque

10. INTRODUCTION

Electric vehicles (EVs) are at the forefront of the automotive industry's transition towards sustainable and energy-efficient transportation [1]. As concerns about climate change and the need to reduce dependence on fossil fuels intensify, the demand for propulsion systems that offer high efficiency, cleanliness, and sustainability has surged [2]. In this context, Permanent Magnet Synchronous Motors (PMSMs) have emerged as a leading choice for electric vehicles due to their superior characteristics, such as high efficiency, high power density, and enhanced controllability compared to other motor types [3].

One of the primary challenges in optimizing PMSM performance is the precise control of motor currents and torque generation [4]. The dq reference frame—a mathematical transformation technique—plays a critical role in refining the control process [5]. By converting the three-phase currents of the motor into a two-axis coordinate system (d and q axes), this technique facilitates independent control of torque and magnetic flux, leading to improved accuracy and efficiency in motor control systems [6].

Recent research has shown that implementing the dq reference frame in PMSM control significantly enhances dynamic response, energy efficiency, and reduces thermal losses in electric vehicle propulsion systems [7]. This article explores the application of PMSMs using the dq reference frame in electric vehicles, emphasizing the benefits and practical implementation of this approach. Through case studies and simulation results, the effectiveness of this method in improving the performance and efficiency of propulsion systems is examined [7][8].

11. Permanent Magnet Synchronous Motor

A Permanent Magnet Synchronous Motor (PMSM) is an AC synchronous machine where the field excitation is provided by permanent magnets. PMSMs are positioned between Induction Motors and Brushless DC Motors (BLDC), featuring a permanent magnet rotor and windings on the stator. The PMSM can be considered a hybrid between an Induction Motor and a Brushless DC Motor. While the rotor and stator windings are similar to those of a Brushless DC Motor, the stator's shape and winding configuration create a sinusoidal flux density in the air gap, similar to that of an Induction Motor. acceptance should be prepared regarding the requested corrections, and the paper should be sent again via conference web site.

2.1 Construction of PMSM

The construction of a PMSM is similar to that of a synchronous motor. The primary difference is that the rotor includes permanent magnets, which are absent in synchronous motors. The stator is equipped with windings that are energized by electrical power, while the rotor is excited by its own permanent magnets. PMSMs are classified into two types:

1. Surface Mounted PMSMs: In this design, permanent magnets are mounted on the surface of the rotor.
2. Buried or Interior PMSMs: In this design, permanent magnets are embedded within the rotor.

Both types of permanent magnet synchronous motors can be used in electric machines. Surface-Mounted PMSM type in electric machines is more suitable for applications with low to medium speed and uniform torque. In this type of motor, permanent magnets are installed on the surface of the rotor, which makes it easy to manufacture and reduce production costs.

However, one of the challenges of using surface-mounted PMSMs in electric machines is the reduction of magnetoresistance, which can reduce performance at high speeds. Therefore, at high speeds and in applications that require dynamic torque and precise control, internal PMSMs are commonly used. But for applications that don't need high speed and prioritize cost reduction and design simplicity, Surface-Mounted PMSM can be a suitable option.

2.2 The difference between these two modes and their uses are summarized as follows

In Permanent Magnet Synchronous Motors (PMSMs), there are two main rotor design types: Surface Mounted PMSMs and Interior PMSMs. These two designs have significant differences that impact their performance and applications.

1. Surface Mounted PMSMs

Rotor Design: In this type of motor, the permanent magnets are mounted on the outer surface of the rotor.

Advantages: The manufacturing and assembly process is simpler due to the external placement of the magnets. Since the magnets are close to the rotor surface, these motors typically have a faster dynamic response.

Disadvantages: The surface-mounted magnets are more exposed to external factors such as heat and mechanical stress, providing less protection. These motors generally produce less reluctance torque compared to interior types.

2. Interior PMSMs

Rotor Design: In this type, the permanent magnets are embedded within the rotor, usually in a buried configuration.

Advantages: Due to the internal placement of the magnets, these motors generate additional reluctance torque, enhancing overall torque performance. The magnets are protected inside the rotor, making them less susceptible to mechanical damage and heat. This rotor design is better suited for high-speed applications due to its robust structure.

Disadvantages: The manufacturing process is more complex and requires greater precision. Due to the more intricate design and the use of better materials, these motors are generally more expensive.

Applications:

Surface Mounted PMSMs: Commonly used in applications that require a fast dynamic response, such as servo motors and some precision control systems.

Interior PMSMs: Typically used in applications requiring high torque and durability at high speeds, such as electric and hybrid vehicles.

12. Working Principle of Permanent Magnet Synchronous Motor (PMSM)

The working principle of a Permanent Magnet Synchronous Motor (PMSM) is based on the interaction between a stationary magnetic field and a rotating magnetic field. When the three-phase windings of the stator are energized, a rotating magnetic field is created in the air gap of the motor. This rotating magnetic field causes the rotor poles to align and lock with it, thereby generating torque that turns the motor shaft.

Synchronous motors, including PMSMs, are not self-starting and require an external means to initiate operation. Since PMSMs may not have windings on the rotor, induction windings for starting are not applicable, and therefore, a suitable frequency strength is needed for the initial startup.

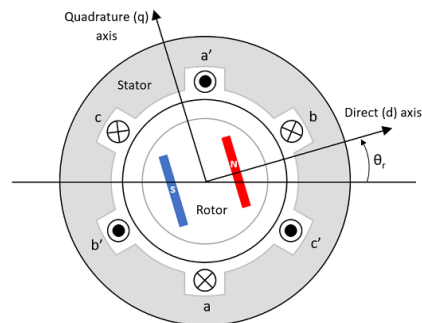


Fig. 1. shows the motor construction with a single pole pair on the motor.[9]

13. dq Reference Frame Transformation

The dq reference frame, also known as Park's transformation, is a mathematical technique used to simplify the analysis and control of AC motors. By transforming the three-phase stator currents into a two-axis coordinate system (d-axis and q-axis), control algorithms can be significantly simplified. This transformation aligns the d-axis with the rotor flux, enabling separate control of torque and flux, thereby improving control precision and motor performance.

4.1 dq Transformation Equations:

1. abc to dq Transformation:

$$\begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ -\sin(\theta) & -\sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (1)$$

2. dq current Equations:

$$\frac{di_d}{dt} = \frac{1}{L_d} (V_d + L_q \omega_e i_q + R_s i_d) \quad (2)$$

$$\frac{di_q}{dt} = \frac{1}{L_q} (V_q - L_q \omega_e i_d - R_s i_q - \varphi_m \omega_e) \quad (3)$$

3. Mechanical Torq Equation:

$$T_m = T_L + B\omega_m + J \frac{d\omega_m}{dt} \quad (4)$$

4. Electromagnetic Torque Equation:

$$T_e = \frac{p}{2} \left(\frac{3}{2} \right) \left((L_d - L_q) i_d i_q + \varphi_m i_q \right) \quad (5)$$

5. Mechanical Speed Equation:

$$\frac{d\omega_m}{dt} = \frac{1}{J} (T_e - T_f - B\omega_m - T_m) \quad (6)$$

Table 1. PMSM Parameter

Parameters	Abbreviated word
Stator phase resistance	R_s
d-axis inductance	L_d
q-axis inductance	L_q
Flux linkage(Wb)	φ_m
Pole pairs	P
Combined viscous friction of motor and load (N·m/(rad/s))	B
Inertia (kg.m ²)	J
Electromagnetic torque (Nm)	T_e
Motor shaft torque (Nm)	T_m
Motor shaft static friction torque (Nm)	T_f
Angular mechanical velocity of the motor (rad/s)	ω_m
Angular electrical velocity of the motor (rad/s)	ω_e

4.2 Benefits of the dq Reference Frame

Decoupled Control: The dq reference frame allows for independent control of torque and flux, which significantly improves the dynamic performance of the motor. By decoupling these two components, the control system can respond more effectively to rapid changes in operating conditions, which is particularly important in electric vehicles (EVs) where driving conditions can change quickly.

Simplified Control Algorithms: The mathematical transformation provided by the dq reference frame simplifies control algorithms by reducing a complex three-phase system into a more manageable two-axis (dq) system. This simplification is crucial for real-time implementation of control strategies, as it reduces the computational load on the control processor, enabling faster and more reliable motor control.

Improved Efficiency: By optimizing the performance of the motor, the dq reference frame enhances energy utilization. This is especially beneficial in electric vehicles, where efficient energy use directly translates into an extended driving range. The improved efficiency also contributes to reducing the overall energy consumption, making the vehicle more environmentally friendly.

Enhanced Responsiveness: The dq reference frame enables faster and more accurate responses to changes in driving conditions. This heightened responsiveness improves the driving experience by providing smoother acceleration, more precise torque control, and quicker adaptation to varying loads and speeds.

4.3 Enhanced Motor Performance

Dynamic Response: The implementation of the dq reference frame allows Permanent Magnet Synchronous Motors (PMSM) to respond more dynamically to changes in load and speed. This capability is critical for electric vehicles, which often face highly variable demands during operation. The dynamic response ensures that the motor can provide consistent performance across a wide range of operating conditions, from low-speed maneuvers to high-speed cruising.

Noise Reduction: Improved control precision, made possible by the dq reference frame, helps in reducing mechanical noise and vibrations. This reduction in noise not only enhances the comfort of the vehicle's occupants but also contributes to a more refined driving experience. Lower noise levels are particularly important in electric vehicles, where the absence of an internal combustion engine makes other sources of noise more noticeable.

Thermal Management: Efficient control strategies facilitated by the dq reference frame lead to reduced heat generation within the motor. Effective thermal management is essential for maintaining the performance and longevity of PMSM. By minimizing heat production, the dq reference frame helps prevent overheating, thereby extending the lifespan of the motor and reducing the need for extensive cooling systems.

14. Differences in Pole Count and Torque for Surface-Mounted PMSM and Interior PMSM

5.1 Surface-Mounted PMSM

Pole Count: In Surface-Mounted PMSM, permanent magnets are mounted on the surface of the rotor. These motors typically have a lower number of poles compared to Interior PMSM, as their design is simpler and more cost-effective. The number of poles affects the motor's performance. More poles can enhance precision and reduce fluctuations in the motor's performance.

Torque: Surface-Mounted PMSM generally produces higher torque at low to medium speeds due to the surface-mounted magnets. However, at high speeds, the magnetic reluctance can increase, potentially reducing efficiency and effective torque. These motors are often suitable for applications where high speed is not required and cost and design simplicity are prioritized.

5.2 Interior PMSM

Pole Count: In Interior PMSM, permanent magnets are embedded within the rotor, leading to increased magnetic reluctance and reduced losses. These motors often have a higher number of poles because the internal design is more complex, which can improve precision and performance at high speeds.

Torque: Interior PMSM typically produces higher torque at high speeds. The embedded magnets result in lower magnetic reluctance, providing better torque performance under various conditions. These motors are preferred for applications requiring high dynamic torque and precise control at high speeds.

6. Simulation and Result

Based on the given values and parameters, we have simulated the PMSM motor in MATLAB Simulink, analyzed, and compared the results for two different poles in both Surface-Mounted PMSM and Interior PMSM configurations. The results have been examined, explained, and compared between these two configurations:

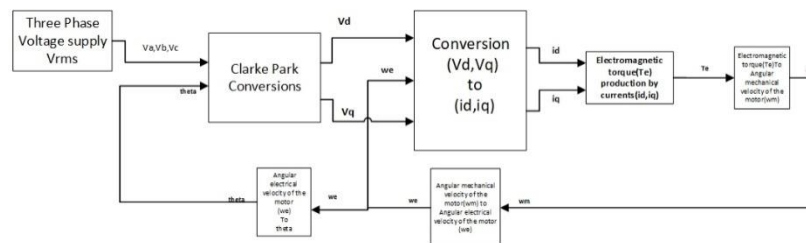


Fig. 2. Block Diagram of PMSM

The block diagram of a Permanent Magnet Synchronous Motor (PMSM) in the ABC to DQ0 transformation can be described as follows:

Three-Phase Inputs (ABC): The primary inputs include the three-phase voltages (V_a , V_b , V_c) and currents (I_a , I_b , I_c) applied to the motor. These three-phase quantities represent the sinusoidal voltage and current signals in the system.

In this stage, the three-phase voltage and current values are transformed into DQ0 components using mathematical techniques outlined in section 4.1.

The transformation is based on the following concepts:

d-axis (Direct Axis): Represents the component aligned with the main magnetic axis (in the direction of the rotor's magnetic field).

q-axis (Quadrature Axis): Represents the component perpendicular to the main magnetic axis.

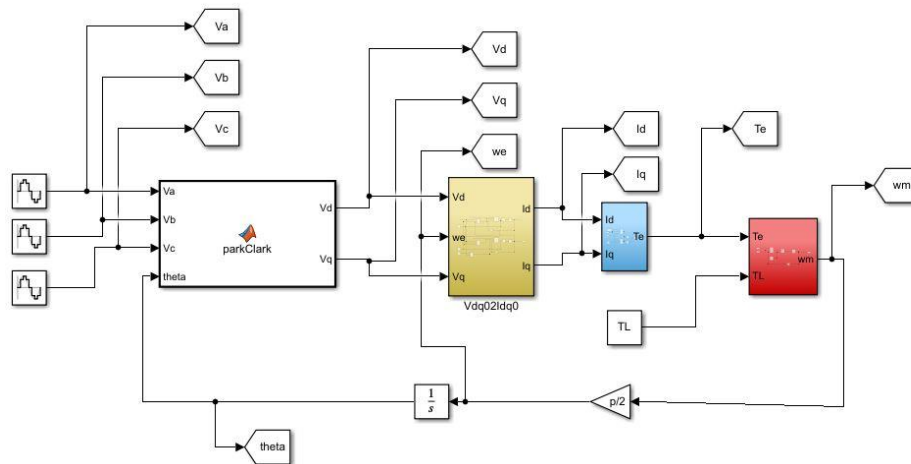
0-axis (Zero Axis): Represents the zero-sequence component, which is typically zero in balanced three-phase systems.

This block diagram is essential for the precise control of the voltages and currents in a PMSM. By utilizing this transformation, torque and speed of the motor can be accurately and optimally controlled.

Table 2. PMSM SPECIFICATIONS

Parameters	Values	Units
R_s	2.8750	Ω
L_d	8.5e-3	H
L_q	8.5e-3/2	H
Φ_m	0.175	Wb
P	2-8	-
B	0.001	$N \cdot m / (rad/s)$
J	0.0008	$Kg \cdot m^2$
V	220	v

Modeling a PMSM in MATLAB in the abc2dq0 frame of reference based on the equations of the section (4.1) and Park's transformation involves the conversion of the three-phase stator currents and voltages (abc) to the direct square zero reference frame (dq0). This transformation simplifies motor control and analysis by separating the torque and flux components.

**Fig.3.** Simulation of PMSM in Simulink MATLAB

Initially, we assume the number of poles=8 and consider the PMSM in the Surface-Mounted configuration.

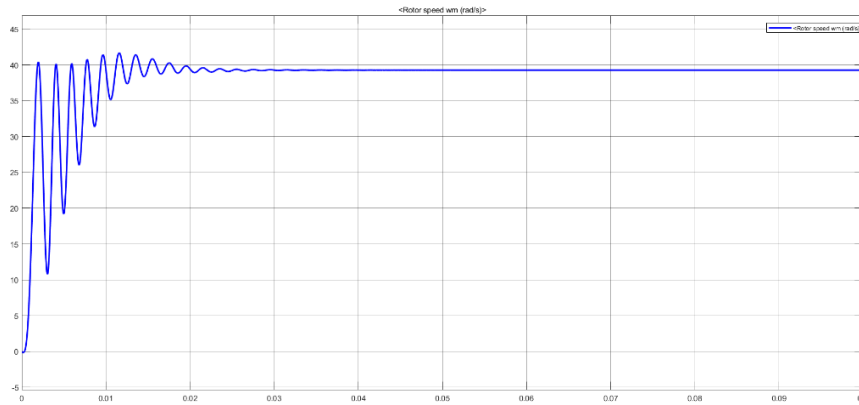


Fig. 4. Rotor speed in Surface-Mounted

We assume the number of poles = 2 and consider the PMSM in the Interior PMSM configuration.

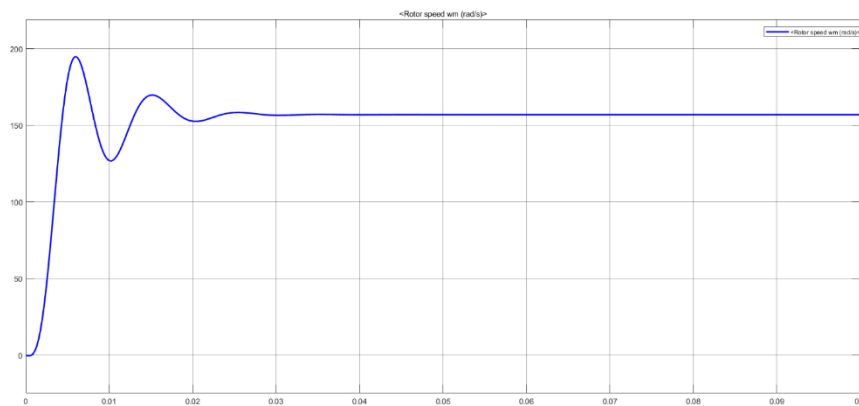


Fig. 5. Rotor speed in Interior

In the first case(Fig 3), where we assumed the number of poles to be 8, the rotor speed (ω_m) is 39.27 rad/sec. In the second case(Fig 4), with 2 poles, the rotor speed is 157.1 rad/sec. Consequently, there is an inverse relationship between the number of poles and the rotor speed. Thus, in the Surface-Mounted configuration, the Rotor speed is lower compared to the Interior PMSM configuration.

The analysis and examination of the currents i_d and i_q are as follows:

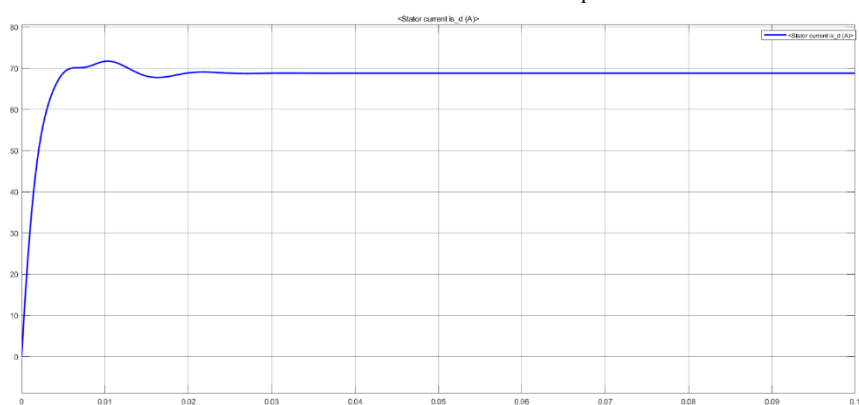


Fig. 6. Stator current i_d

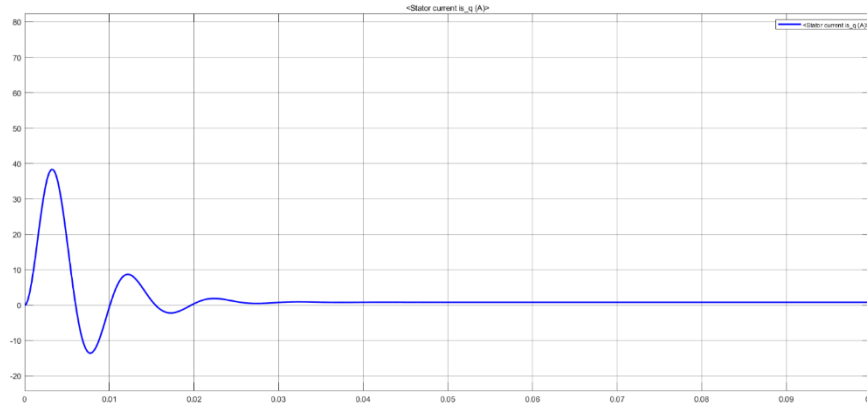


Fig. 7. Stator current i_q

In the ABC to DQ0 transformation:

D-axis current (i_d): This current is used to control the magnetic flux in the motor. By adjusting I_d , the magnetic flux within the motor can be regulated.

Q-axis current (i_q): This current is responsible for torque production. Changes in I_q directly lead to variations in the motor's output torque.

Therefore, i_q typically has a significant value, and if this value approaches zero, the motor's generated torque will also decrease.

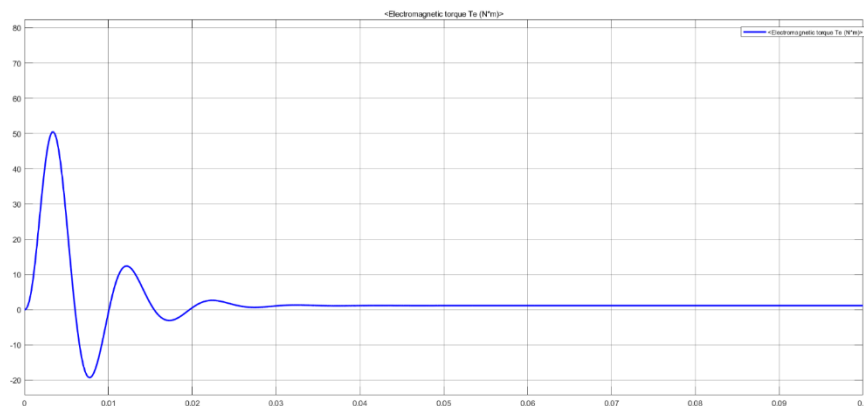


Fig. 8. Electromagnetic Torque (T_e)

Figure 7 confirms that the relationship between the current i_q and torque is a direct and proportional one. It should be noted that due to the higher speed in the Interior PMSM, the torque in this configuration is lower compared to the Surface-Mounted PMSM.

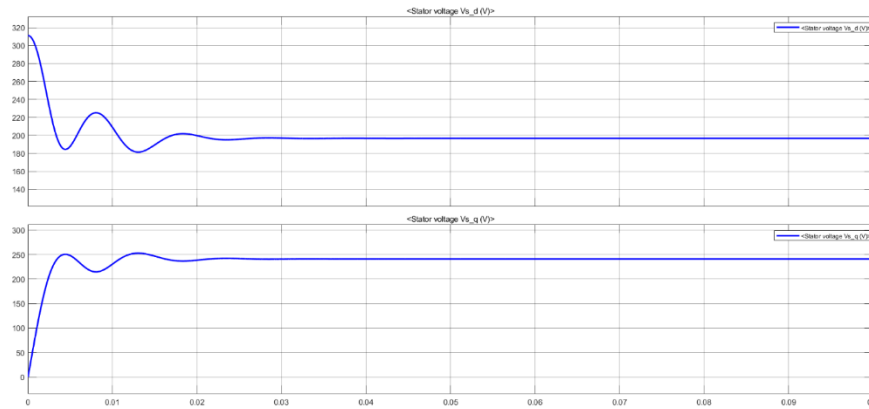


Fig. 9. Stator Voltage (V_d, V_q)

The ratio and magnitude of V_d and V_q have a direct impact on the performance of the motor, and they must be properly adjusted to achieve optimal performance and reduce energy losses. In summary, V_d helps control the magnetic flux, while V_q contributes to torque control in the motor. Changes in these two values affect the overall performance of the PMSM motor.

7. Conclusion

Permanent Magnet Synchronous Motors (PMSMs) are highly efficient and versatile electric motors that offer significant advantages for use in electric vehicles (EVs). Their high power density, excellent efficiency, and robust performance make them ideal for driving EVs. The design of PMSMs, whether in the form of Surface-Mounted or Interior configurations, allows for adaptability to various requirements. Surface-Mounted PMSMs are typically preferred for applications where cost efficiency and simpler design are prioritized, while Interior PMSMs are better suited for high-speed applications where robust performance and dynamic torque control are essential.

In the context of electric vehicles, the use of PMSMs contributes to extending driving range due to their high efficiency and low energy consumption. Their compact size and ability to provide high torque make them well-suited for the demands of modern EVs, ensuring smooth operation and reliable performance. The adaptability of PMSM designs further supports their application across a wide range of electric vehicle models, from compact cars to high-performance electric sports cars. Overall, PMSMs are a key component in the advancement of electric vehicle technology, driving the shift towards more sustainable and energy-efficient transportation solutions.

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Copper nanoparticles and investigating the antimicrobial and anticancer effects of these particles (A review study)

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ABSTRACT

The use of copper in medicine is not a new issue and goes back to ancient Egypt between 2600 and 2200 BC. Old documents state that copper was used in medicine to sterilize chest wounds and drinking water. The Greeks, Romans and Aztecs also used copper compounds to treat problems such as burns, intestinal worms, ear infections and generally to maintain health. Recent scientific studies clearly show that copper nanoparticles and copper-containing alloys quickly destroy bacteria, yeasts and viruses on their surface. This would require the reintroduction of copper nanoparticles, brass, bronze and other copper-rich alloys into the hospital to create antimicrobial surfaces. The so-called "contact killing" occurs very quickly and completely on metal surfaces containing copper nanoparticles. Therefore, copper nanoparticles offer a promising horizon for different applications in nanobiotechnology and medicine. In this review article, the validity of the studies up to date has been examined, and through searching in databases such as Google Scholar, Scopus, PubMed and other reliable databases, the latest information about copper nanoparticles and applications have been obtained by searching for specialized keywords.

Keywords: Copper nanoparticles, Antimicrobial, infections

1. INTRODUCTION

A copper nanoparticle is a particle of 1 to 100 nanometers based on copper. Copper nanoparticles, like many other forms of nanoparticles, can be formed through natural processes or chemical synthesis. With their small size and large porosity, copper nanoparticles are able to react more in less time as reagents in organic synthesis and organic metals. In fact, about 88% of copper nanoparticles are converted to biphenyl in the iodobenzene condensation reaction, while only 43% of copper metal can be converted in this reaction. Various methods are available to produce chemically synthesized copper nanoparticles. Currently, for the production of copper nanoparticles, copper chloride is used during the reaction with sodium citrate or myristic acid in an aqueous solution containing formaldehyde sulphosylate acid at room temperature, and copper hydrazine carboxylate salt (II) is used using ultrasound or heat. in water to produce a radical reaction. Copper nanoparticles can also be synthesized using environmentally friendly chemicals to reduce the environmental effects caused by the reaction. Copper nanoparticles are very small and have a high contact surface compared to their volume and can act as antifungal or antibacterial substances [1]. Copper nanoparticles with excellent catalytic activities can be used for electrochemical sensors and biosensors. Oxidation-reduction reactions in these sensors are generally irreversible and also require more energy to run. In fact, copper nanoparticles have the ability of reversible oxidation-reduction reactions and reduction of overpotential when used for sensors. One example is the glucose sensor. By using copper nanoparticles, this sensor does not need enzymes and does not need to deal with enzymatic decomposition and artificiality. In fact, nanoparticles make the sensor more stable at high temperatures and different pH, making it more resistant to toxic chemicals. In addition, by using copper nanoparticles, native amino acids can be identified [2].

One of the first applications of copper nanoparticles was the coloring of glass and ceramics, which was done by creating a glaze with copper and silver salts. When pottery is fired under reducing conditions at high temperature, metal ions transfer to the outer part of the glaze and are reduced to metal. Copper nanoparticles are also of particular interest as pigments and modern biomedical materials. Copper nanoparticles have unique properties such as catalytic and antifungal or antibacterial activities that cannot be seen in copper metal itself [3].

1.1 Copper nanoparticles (Cu NPs)

Copper nanoparticles (CuNPs) have obtained public interest due to their mechanical, electrical, magnetic and thermal properties and they have been used in water treatment, heat transfer systems and antimicrobial coating for surgical tools.

An advantage to using copper is that it is cheap and widely available, thus obtaining CuNPs is cost effective. One of the downsides of CuNPs is that when exposed to aqueous environments, they are susceptible to oxidation. Copper transforms into CuO and Cu₂O, and converts to Cu²⁺ during preparation, imposing challenges in further synthesizing CuNPs in an ambient environment [4].

Studies in the synthesis and research on nanoparticles have been carried out, for example, a group of researchers, analyzed the oxidation of copper nanoparticles in relation to temperature. The threshold temperature was recognized between 190 and 200 °C. The analysis was then performed using nanoparticles treated at 170 and 240 °C for 200 min and after their chemical composition was studied. Below the threshold temperature, the resulted particles were mainly Cu₂O. Above the threshold temperature, Cu₂O was initially obtained, which then changed to CuO [5]. In a different study, the authors discuss the use of carbon-encapsulated copper nanoparticles. Carbon coating can prevent oxidation and have a few advantages over CuNPs, such as good compatibility with organics, highly pressure- and temperature-dependent electrical conductivity and excellent electromagnetic wave loss ability. The authors have concluded that the outside carbon shell can prevent oxidation of the copper inside at temperatures up to 900 °C [6].

1.1.1 Features of copper nanoparticles

1. High surface area and the possibility of more chemical and physical interactions
2. face-centered cubic structure
3. These spherical nanoparticles have high amounts of light absorption in the wavelength range of 400-600 nm. These properties allow copper nanoparticles to be used as an active material in nanoelectronic structures, sensors, and catalysts.
4. These compounds with a diameter smaller than 5 nm have a wide absorption spectrum in the near-ultraviolet wavelength range.
5. These nanoparticles with a size smaller than 50 nm have a dark red color, while particles with a size between 50 and 100 nm have a light red color and with a size larger than 100 nm have a light-yellow color [7].

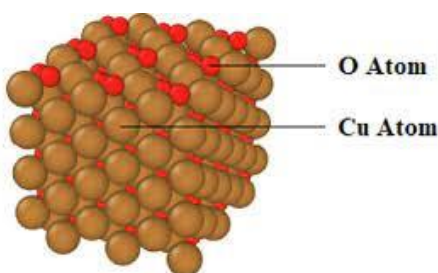


Fig. 1. The atomic arrangement of CuO NPs with cubic shape

1.2 Synthesis techniques of copper nanoparticles

In general, nanoparticle synthesis methods are usually divided into two categories: physical and chemical techniques. The physical method involves the reduction of bulk solids into smaller pieces of very fine grains through a grinding process, either by using acidic materials or by using energy sources. The grinding process is the most obvious example of physical methods, while highly efficient mills are used to separate nanometer-sized particles [8]. However, this is not a reliable system for obtaining metal nanoparticles, because in general, the obtained particles are larger than 100 nm, which cannot be considered in nanometer size. Another weakness of this technique is the energy used for grinding, which must be continuous and can show energetic changes to the production of solids, which causes a significant imbalance that leads to a decrease in the amount of energy activation. In fact, it is probably one of the oldest methods, but nowadays it is not used to obtain copper nanoparticles with regular size and defined morphology [9].

1.2.1 Physical methods

Physical techniques are impractical methods, such as those requiring vacuum or plasma, sometimes yielding low-quality nanoparticles. A few physical methods are incorporated during or after a chemical process, for example, laser ablation that requires a colloidal solution that has a chance to oxidize on the surface of nanoparticles in a combustion chamber in order to remove or extract atoms from the bulk surface by diffusion. minimizes the laser beam; This method is not possible due to the complexity of the equipment and the use of high energy for the laser [10].

1.2.2 Chemical synthesis methods

Various chemical methods are used to obtain nanoparticles, such as sonochemical reduction, hydrothermal synthesis, electrochemical and chemical reduction. The latter is the most commonly used one. It involves using hydrazine, ascorbic acid or sodium borohydride as a reducing agent. The chemical reduction method is often used to obtain CuNPs because it is simple, has high yield efficiency and requires limited equipment [11]. The chemical conversion method and the microemulsion route are used for the first time to make gold metal and from them to reduce other noble copper metals using copper salts (sulfates, nitrates and chlorides) and its reducing agents [12]. We can list the microemulsion reduction method, also known as colloidal synthesis, as one of the chemical techniques. It involves the formation of active surface microarrays by combining water and soil, water and oil, and supercritical carbon dioxide. Ultrasonic waves, which have a frequency of between 20 kHz and 10 MHz, are the basis for the reduction of cell death. The acoustic cavity's physical properties cause this reaction to occur. The application of electricity between two electrodes—the cathode and anode—that have been separated by an electrolytic solution is the foundation of electrochemical synthesis. This alternative method involves the reduction process taking place on the cathode electrode's surface [13]. The application of electricity between two electrodes—the cathode and anode—that have been separated by an electrolytic solution is the foundation of electrochemical synthesis. This alternative method involves the reduction process taking place on the cathode electrode's surface. New methods for obtaining regular copper nanoparticle shape and particle size include hydrothermal treatments and microwaves. The microwave approach uses electromagnetic energy at frequencies between 300 MHz and 300 GHz, where enough energy has a direct impact on the copper nanoparticles' structure. Lastly, a tightly sealed autoclave is needed for the chemical reaction in hydrothermal treatment, when the solvents are heated over their boiling temperatures [14].

1.2.3 Green synthesis method

Green synthesis of metallic nanoparticles is widely used because of its harmless obtaining method. It uses molecules in plants and microorganisms (bacteria, fungi) as a reducing agent. It has the advantage of using more eco-friendly materials, being cheaper than chemical synthesis, simpler, more rapid and sustainable. It is preferable to use plant extracts to obtain nanoparticles rather than using microorganisms because of increased difficulty in preserving cell cultures. Moreover, it reduces the complex process of maintaining cell cultures and it is also suitable for creating large scale synthesis of nanoparticles [15]. Considering the use of nanoparticles in medicine, there is an increased need to use an eco-friendly method of obtaining as they are regarded as the next step in battling diseases. Several

studies have been done in this field. For example, IN the study in 2020, The *Rhuscoriaria* L. fruits extract was mixed with copper sulphate solution and hydrazine hydrate as reducing agent and sodium hydroxide as catalyst. The solution heated to a temperature of 60 °C and the reduction reaction was followed by observing the color change. The synthesized CuNPs were characterized by UV–Visible spectra, FTIR, XRD and TEM. CuNPs display an absorption peak at 560 nm. TEM photograph showed that synthesized CuNPs had semi-spherical shapes with diameter of 22–27 nm. The XRD data exposed that the average crystallite size was 18 nm. Parameters such as direct energy band gap (DEBG), indirect energy band gap (IDEBG), Urbach energy (EU) and Fermi energy (EF) were calculated by using UV–Visible absorption. CuNPs had shown an inhibitory effect versus Gram-positive bacteria during the antimicrobial studies [16].

In 2018, Nagar et al did interesting research. In this report, copper nanoparticles were synthesized by the leaf broth of *Azadirachta indica* and the effect of different reaction parameters such as precursor salt concentration, leaf broth percentage, temperature and pH of the medium on the conversion rate and morphology of the CuNPs were analyzed. The plant biomolecules induce the reduction of Cu^{2+} ions to CuNPs and also act as a capping and stabilizing agent. The formation of CuNPs was monitored by absorbance spectra of UV-visible spectrophotometer at different stages during the synthesis process. The biosynthesized CuNPs were characterized by different instrumental techniques and results described. The particles are crystalline, cubical shape with the average size of 48nm and highly stable. The optimum conditions for synthesis are as follows: percentage of leaf broth 20%, $[\text{CuCl}_2] = 7.5 \times 10^{-3}\text{M}$, pH 6.6 and temperature 85°C. The present study could prove to have an enormous impact in the immediate future to synthesize metallic nanoparticles on an industrial scale [17].

Various methods can be used to stabilize these nanoparticles. One of the stabilization methods is the use of chemical stabilization agents. In this method, first the produced nanoparticles are placed in the solution and then chemical stabilization agents such as polymer molecules, amino compounds, fatty acids, etc. are added to them to give them more stability [18].

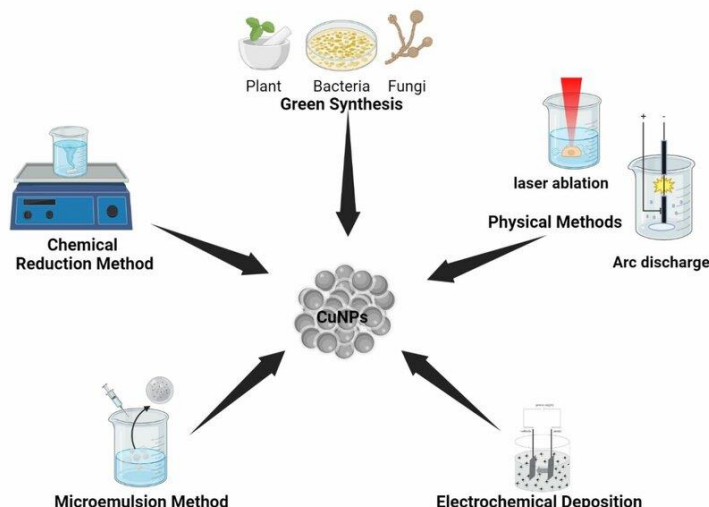


Fig. 2. Different Methods of Copper Nanoparticles Synthesis

1.3 Some applications of copper nanoparticles in medicine

Formulations based on nanomaterials are essential to the global healthcare system. Novel nanomedicines can be employed as drug delivery systems for the treatment of neurological, cardiovascular, immunological, and respiratory disorders, as well as cancer and bacterial and viral infections. When used as contrast agents in magnetic resonance imaging (MRI) or as PET tracers, nanoformulations can be beneficial in bioimaging and diagnostic procedures. The primary benefit of nanomedicines is their versatility. A theranostic technique is created by nanomaterials that offer

both targeted detection and treatment capabilities at the same time. Furthermore, nanomaterials can be utilized to customise a therapeutic agent to a particular target in a single patient suffering from a given illness, advancing the field of personalised medicine [19] and [20].

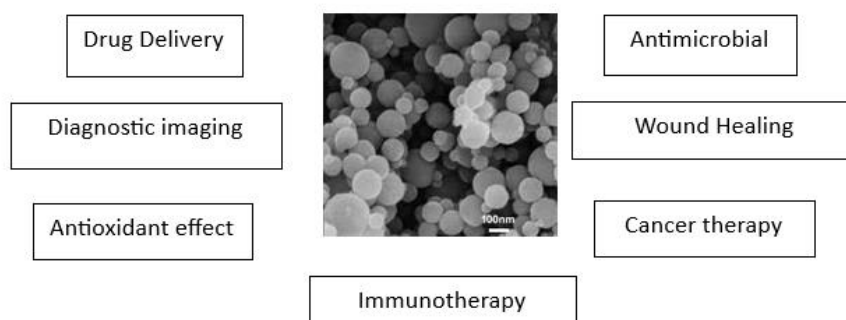


Fig. 3. Some applications of copper nanoparticles in medicine

1.3.1 Anticancer Effect

Copper nanoparticles can be utilised as anticancer therapeutics or effective drug nanocarriers due to their large specific surface area that facilitates conjugation with various biomolecules. In general, it can be said that Copper nanoparticles and its complexes can induce autophagy or apoptosis in tumor cells through a variety of different mechanisms of action (activation of stress pathways, arrest of cell cycle, inhibition of angiogenesis, cuproptosis, and paraptosis), which are promising in cancer therapy [21].

Kang et al, designed copper diethyldithiocarbamate nanoparticles ($\text{Cu}(\text{DDC})_2$ NPs) to overcome resistance in prostate cancer therapy. Based on in vivo studies (xenograft tumour model in male athymic nude mice), it was assumed that $\text{Cu}(\text{DDC})_2$ NPs prevent cancer cell metastasis and treat resistance by by-passing P-glycoprotein (P-gp) mediated drug efflux transporters, which are responsible for removal of anticancer drugs out of cells. Moreover, it was shown that $\text{Cu}(\text{DDC})_2$ NPs did not interfere with normal P-gp activities in the body, which is very important because these transporters play a vital role in toxin elimination in healthy tissues [22].

Copper oxide(II) nanoparticles coated with fucoidan derived from *Undaria Pinnatifida* algae exhibited antiproliferative and genotoxic effects on HeLa cells. Additionally, fucoidan-modified CuO NPs demonstrated the ability to modulate the apoptosis of cancer cells via activation of apoptosis-related proteins, including B-cell lymphoma 2 (BCL2), Bcl-2-associated X protein (BAX), cleaved caspase-3 [23]. Copper oxide (II) nanoparticles have been shown to be effective in the treatment of human pancreatic cancer in vitro and in vivo (mice model). The inhibition of tumour growth was related to increased ROS levels and reduction of the mitochondrial potential of the cancer cell membrane. Scientists from China Pharmaceutical University published interesting in vivo research on encapsulated copper sulfide nanoparticles for combined photothermal and chemotherapy [24].

In 2021, a group of Iranian researchers investigated copper nanoparticles stabilized with starch on breast cancer cell lines. Standard colorimetric MTT and LDH assays were used to estimate the cytotoxic effect of CuNPs on MCF-7 and LoVo cells. Furthermore, CuNP-treated cells undergoing apoptosis were assessed based on the expression of apoptosis-related genes using qRT-PCR. The results indicated that the mean particle size of the synthesized CuNPs was ~50–60 nm, and they were spherical in shape with mainly the chemical structure of the copper metallic phase. MTT assay revealed that CuNPs induced cytotoxicity in tested cells with IC₅₀ rates of 16.4 (in MCF-7) and 21.6 µg/ml (in LoVo). Moreover, qRT-PCR analysis showed that CuNPs caused a significant increase of Bax, P53, and

Caspases 9, 8, and 3 genes. Overall, the anticancer potential of prepared CuNPs were reported through apoptotic induction which highlights the potential use of CuNPs as an efficient anticancer agent [25].

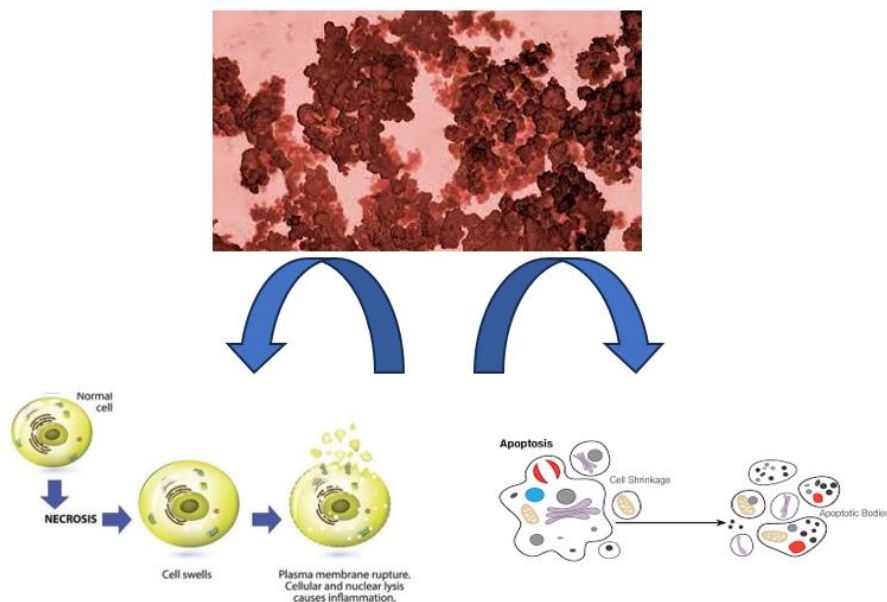


Fig. 4. Effects of copper nanoparticles on cancer cells

1.3.2 Antibacterial effect

Nanoparticles can reduce or stop the evolution of resistant bacteria because nanoparticles (NPs) target multiple biomolecules at once. The Gram-positive bacteria present only a thicker peptidoglycan layer in the cell wall. Research shows that Gram-positive bacteria have a higher resistance to the nanoparticle's mechanism of action. The additional outer layer of Gram-negative bacteria is coated in lipopolysaccharide. Which has a negative charge. The ions released by nanoparticles have a positive charge. Giving them a high affinity for the negative molecules present in the cell wall. This attraction leads to a buildup and intake of ions which lead to intracellular damage [26] and [27]. Both types of bacteria have negatively-charged walls which influence the interaction between nanoparticles and the ions released. Studies with *Salmonella typhimurium*, (a Gram-negative bacteria), show that the bacterium's cell wall is populated with a mosaic of anionic surfaces. This facilitates the formation of areas with high concentration of nanoparticles binding to the cell wall which leads to an increased toxicity [28].

Besides the interaction of copper nanoparticles with bacteria's cells, copper ions can interact with DNA, intercalate with nucleic acid strands and can disrupt biochemical processes. Ions of copper can also produce hydroxyl radicals which damage essential proteins [29] and [30].

In 2014, scientists investigated the effect of copper oxide nanoparticles on *E. coli* bacteria. This work investigated the role of oxidation state in the antibacterial activity of copper oxide nanoparticles (NPs). The findings added strong support to a contact killing mechanism of copper oxides (CuO and Cu₂O) through which bacteria initially suffer severe damage to the cell envelope. Then further damage ensues by an independent pathway of each copper oxide nanoparticle. Formation of copper(I)–peptide complex from cuprous oxide (Cu₂O) and free radical generation from cupric oxide (CuO) were identified as key sources of toxicity towards *E. coli*. Cu₂O rapidly inactivated Fumarase A, an iron sulphur cluster enzyme suggesting the cuprous state of copper binding to the proteins. This inactivation was not noticed in CuO. The percentage of biocidal/bacteriostatic activity is closely related to the oxidation state of the copper oxides. In the case of *E. coli*, Cu₂O nanoparticles showed more efficient antibacterial activity and higher affinity to the bacterial cells. CuO nanoparticles produced significant ROS in terms of super oxides while Cu₂O did

not. The diminishing defective emission peaks of Cu₂O after incubation with microbes strongly suggest the formation of protein complexes [31].

In a Study, Copper oxide (CuO) nanoparticles (NPs) doped with Mg²⁺, Zn²⁺ and Ce⁴⁺ ions were prepared by a hydrothermal method. SEM images revealed a spherical surface morphology for all doped CuO NPs. XRD patterns confirm that all doped CuO NPs exhibit a monoclinic structure at a dopant concentration of less than 7%, and when the doping content is up to 10%, MgO, ZnO and CeO₂ phases are formed. ICP analysis indicated that these three doping elements have a promoting effect on the release of Cu²⁺ from the doped CuO NPs. Moreover, investigation of the antibacterial activity of the doped CuO NPs reveals that the doped CuO nanoparticles show effective antibacterial activity against Gram-positive *Staphylococcus aureus* (*S. aureus*) compared to the Gram-negative *Escherichia coli* (*E. coli*) bacterium. Among them, 5% Mg, 3% Zn and 5% Ce-doped CuO NPs exhibit the best bactericidal effect at a very low concentration of 0.05 mg mL⁻¹, and the highest bacteriostatic rate can reach 99.9%. The improved antibacterial activity of the doped CuO NPs was attributed to the synergetic effect of ROS generation and the inactivation of proteins in the bacterial cells by the binding of the Cu²⁺ ions to the bacterial cell surface. This work highlights the potential of the doped CuO NPs to replace silver for antibiotic-free antibacterial applications in wound dressings, bone implants and dental fillings [32].

In a concern in 2020, Cu and CuO nanoparticles (NPs) were successfully synthesised from copper scrap using plasma arc discharge method under N₂ and air atmosphere. The synthesised NPs were confirmed using X-ray diffraction, UV-visible spectrophotometer and energy-dispersive spectroscopy. High-resolution transmission electron microscopy was carried out to study the morphology and average particle size of synthesised NPs. The results revealed that the particles exhibit spherical and distorted sphere morphology with average particle size of 78 nm and 67 nm for Cu and CuO NPs, respectively. The antibacterial activity has been examined against different gram-positive and gram-negative bacteria. The highest zone of inhibition was measured as 32 mm and 28 mm for *Staphylococcus aureus* and *Klebsiella pneumoniae* bacteria which indicates the potent of synthesised NPs in various biomedical applications that can be explored in future [33].

In a study in 2023, Copper oxide nanoparticles (CuONPs) were synthesized using an eco-friendly method and their antimicrobial and biocompatibility properties were determined. The supernatant and extract of the fungus *Ganoderma sessile* yielded small, quasi-spherical NPs with an average size of 4.5 ± 1.9 nm and 5.2 ± 2.1 nm, respectively. Nanoparticles were characterized by UV-Vis spectroscopy, transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), dynamic light scattering (DLS), and zeta potential analysis. CuONPs showed antimicrobial activity against *Staphylococcus aureus* (*S. aureus*), *Escherichia coli* (*E. coli*), and *Pseudomonas aeruginosa* (*P. aeruginosa*). The half-maximal inhibitory concentration (IC₅₀) for *E. coli* was 8.5 µg/mL, for *P. aeruginosa* was 4.1 µg/mL, and for *S. aureus* was 10.2 µg/mL. The ultrastructural analysis of bacteria exposed to CuONPs revealed the presence of small CuONPs all through the bacterial cells. Finally, the toxicity of CuONPs was analyzed in three mammalian cell lines: hepatocytes (AML-12), macrophages (RAW 264.7), and kidney (MDCK). Low concentrations (<15 µg/mL) of CuONPs-E were non-toxic to kidney cells and macrophages, and the hepatocytes were the most susceptible to CuONPs-S. The results obtained suggest that the CuONPs synthesized using the extract of the fungus *G. sessile* could be further evaluated for the treatment of superficial infectious diseases [34]. According to the current studies, copper nanoparticles in various free and combined forms can be a suitable strategy for the treatment of resistant bacterial infections.

1.3.3 Antiviral effect

The ability of copper nanoparticles to generate ROS makes them a potent antiviral agent. Several reports mention the antiviral activity of copper nanoparticles, meaning that the metal nanoparticles also have promising antiviral activities [35]. In a study, an extract of *Juglans regia* green husk was used to biosynthesize copper-oxide nanoparticles (CuONPs). The cytotoxicity of NPs was evaluated by MTT assay. Different treatment assays were conducted. Another assay was designed to employ the concentration of 300 µg/ml of CuONPs, which is the highest concentration that did not precipitate. Finally, chemically synthesized iron oxide nanoparticles (FeNPs) were used to adsorb CuNPs. The

antiviral effect of FeNPs was investigated, separately. Docking results confirmed that NPs could interact with the HSV-1 glycoproteins and prevent viral entry. MTT assay results illustrated that the minimum non-toxic concentration (MNTD) of CuNPs is 100 µg/ml which did not exhibit antiviral properties. Employing a noncytotoxic concentration of FeNPs (300 mg/ml) in combination with cytotoxic concentration of CuNPs (300 µg/ml), eliminated the cytotoxicity effects of CuNPs. Exposure of the virus with the combination of CuNPs and FeNPs resulted in 4.5 log₁₀ TCID₅₀ reductions in HSV-1. While treating HSV-1 with only FeNPs, the virus titer was reduced by 3.25 log₁₀ TCID₅₀. The result was that the combination of CuNPs and FeNPs have antiviral activity against HSV-1. Moreover, FeNPs demonstrated antiviral properties against HSV-1 separately [36]. In a study conducted by Guo et al, they synthesized 4±0.5 nm copper (I) sulfide (Cu₂S) nanoparticles (NPs) with 46 mdeg chiroptical property at 530 nm to selectively cleavage HBV core antigen (HBcAg) and effectively blocked HBV assembly and prevented HBV infection both in vitro and in vivo under light at 808 nm. Experimental analysis showed that the chiral Cu₂S NPs specific bound with the functional domain from phenylalanine²³ (F23) to leucine³⁰ (L30) from HBcAg primary sequence and the cutting site was between amino acid residues F24 and proline²⁵ (P25). Under excitation at 808 nm, the intracellular HBcAg concentration was reduced by 95 %, and in HBV transgenic mice, the levels of HBV surface antigen (HBsAg) and HBV DNA were decreased by 93 % and 86 %, respectively. Together, these results reveal the potential nanomedicine for HBV control and provide fresh tools for viral infection [37].

1.3.4 Antifungal effect

For many years' copper has been used as a material in the manufacturing process of pesticides, fungicides and fertilizers. Given the latest technology developments, it has been claimed that copper nanoparticles can be used as a good fungicide. Studies reported that CuNPs can be used as fungicide against a broad range of plant fungi, such as *Fusarium* sp., *Phoma destructiva*, *Curvularia lunata*, *Alternaria alternata*, *Fusarium oxysporum*, *Penicillium italicum*, *Penicillium digitatum* and *Rhizoctonia solani* [38].

For example, Priya's study investigated the synthesis of CuO NPs with aqueous extract of *Morinda citrifolia* as a stabilizing agent. The leaf extract of *Morinda citrifolia* was mixed with a solution of copper sulphate (CuSO₄·5H₂O) and sodium hydroxide as a catalyst. UV–visible spectroscopy, FTIR, XRD, SEM, TEM, and EDAX analysis were performed to study the synthesized CuO NPs. Particle size distribution of the synthesized CuO NPs have been measured with dynamic light scattering. The CuO NPs synthesized were highly stable, sphere-like, and have size of particles from 20 to 50 nm. Furthermore, as-formed CuO NPs shown strong antibacterial activity against the Gram-positive bacteria (*Bacillus subtilis*, and *Staphylococcus aureus*), and Gram-negative bacteria (*Escherichia coli*). CuO NPs revealed a similar trend was analysed for antifungal activity. The zone of inhibition for the fungi evaluated for *Aspergillus flavus* (13.0 ± 1.1), *Aspergillus niger* (14.3 ± 0.7), and *Penicillium frequentans* (16.8 ± 1.4). According to the results of this investigation, green synthesized CuO NPs with *Morinda citrifolia* leaf extract may be used in biomedicine as a replacement agent for biological applications [39].

In 2023 in a study, bimetallic zinc oxide-copper oxide nanoparticles (ZnO-CuO NPs) were myco-synthesized using *Aspergillus fumigatus* for controlling *Fusarium oxysporum* growth. *Aspergillus fumigatus* was isolated from soil and identified morphologically and genetically. The myco-synthesized ZnO-CuO NPs were characterized using UV-Vis, DLS, HR-TEM, SEM, and XRD analyses. HR-TEM characterization method indicated that, the biosynthesized bimetallic ZnO-CuO NPs appeared as semi-spherical with the average diameter specified as 54.18 ± 1.9 nm. The DLS method described the characteristic particle size diffusion and was calculated as 85.52 nm, 90.85 nm, and 92.85 nm for ZnO NPs, CuO NPs, and ZnO-CuO NPs, respectively. Additionally, the SEM image of ZnO-CuO NPs displays basic NP surface character and the exterior impression was apparent. The biosynthesized ZnO-CuO NPs were separated naturally as spherical particles connected within the fungal filtrate, which displays as illuminated NPs fused and capped with the fungal filtrate. Antifungal activity of bimetallic ZnO-CuO NPs was evaluated against *F. oxysporum*. Results revealed that bimetallic ZnO-CuO NPs exhibited promising antifungal activity toward *F. oxysporum* where inhibition zone at 1000 µg/ml was 22.8 ± 0.76 mm, and MIC was 125 µg/ml. Moreover, growth inhibition percentages of *F. oxysporum* at different concentrations of bimetallic ZnO-CuO NPs 1000, 500, 250, and

125 µg/ml were 88.9, 65.5, 41.1, and 8.9% respectively, where the highest inhibition was 88.9% at concentration 1000 µg/ml, while the lowest inhibition was 8.9% at concentration 125 µg/ml. In TEM ultrastructure results, the treated *F. oxysporum* with ZnO-CuO NPs, a clear destruction was found in all cell contents and disintegration of the cell wall as well as destruction of the plasma membrane. Also, the nucleus appeared as small size and damaged shape and the chromatin materials distributed with several dark stained bodies in cytoplasm. In conclusion, bimetallic ZnO-CuO NPs were successfully myco-synthesized using *A. fumigatus*, where it had promising antifungal activity against *F. oxysporum* [40].

In a case, researchers, a nanocomposite based on mycosynthesized copper oxide nanoparticles (CuONPs), nanostarch, nanochitosan was prepared. Results illustrated that twenty-four *Candida* isolates were isolated from clinical samples. Furthermore, three *Candida* strains were selected as the most resistant among others toward commercial antifungal drugs; these selected strains were identified genetically as *C. glabrata* MTMA 19, *C. glabrata* MTMA 21 and *C. tropicalis* MTMA 24. Characterization of the prepared nanocomposite was carried out using physiochemical analysis included Ultraviolet-visible spectroscopy (Uv-Vis), Fourier-Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray spectroscopy (EDX) and Transmission Electron Microscopy (TEM). Moreover, the nanocomposite exhibited promising anticandidal activity against *C. glabrata* MTMA 19, *C. glabrata* MTMA 21 and *C. tropicalis* MTMA 24, where the inhibition zones were 15.3, 27 and 28 mm, respectively. Ultrastructure changes observed in nanocomposite-treated *C. tropicalis* demonstrated disruption of the cell wall which led to cell death. In conclusion, their results confirmed that the novel biosynthesized nanocomposite based on mycosynthesized CuONPs, nanostarch and nanochitosan is a promising anticandidal agent to fight multidrug-resistant *Candida* [41].

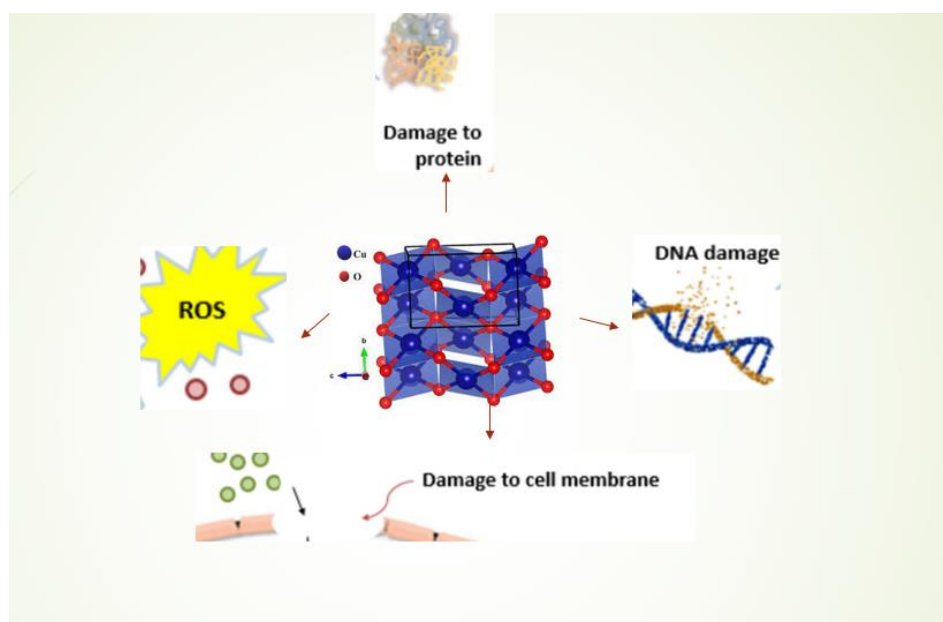


Fig. 5. Antimicrobial mechanisms of copper oxide nanoparticles

2. CONCLUSION

Copper nanoparticles are small nanometer particles. Due to their individual characteristics, these particles have attracted the attention of many researchers in various fields including nanotechnology, electronics and medicine. copper nanoparticles can be obtained using green, chemical and physical methods. Copper nanoparticles interact with the bacteria's cell wall, DNA, nucleic acid. Nanoparticles are responsible for ROS generation and oxidative stress. This eventually leads to cell death. Also, copper nanoparticles have unique properties in the treatment of cancer cells

by inducing cell death and apoptosis. Due to the unique properties of these nanoparticles, they can be used in medicine to treat many diseases in different ways.

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Fabrication and Investigation the Structural and Morphological Properties of MoO₃/Ag/Cu/MoO₃ Multilayer Nanostructures

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Abstract

In this article, three transparent conductive electrodes MoO₃/Cu/MoO₃ and one four-layer transparent conductive electrode MoO₃/Ag/Cu/MoO₃ were fabricated. The three-layer structures were prepared with different thicknesses of copper layering, while the four-layer structure was made under the same conditions on glass substrates using the magnetron sputtering method and after fabrication, the structural and morphological properties of these nanostructures were investigated. In all samples, the thickness of the MoO₃ layers was fixed at 50 nm. The layering time for copper metal in the first sample was 50 seconds, in the second sample was 100 seconds, and 150 seconds for the third sample. Additionally, in the four-layer structure, a silver layer was added to the copper layer. In this sample, the layering time for silver was 30 seconds and for copper was 70 seconds. The changes in the mentioned properties under annealing at a temperature of 400 degrees Celsius were studied for one hour, and the changes in their characteristics were compared with the samples before annealing. For a detailed examination of structural and morphological properties of these electrodes, XRD and FESEM analyses were used. The XRD results showed that the MoO₃/Cu/MoO₃ sample, which had a copper layering time about 50

seconds, exhibited a disordered structure. The second sample displayed several peaks corresponding to the orthorhombic phase of α -MoO₃ and the hexagonal phase of MoO₃. These peaks appeared with greater intensity in the third sample. The MoO₃/Ag/Cu/MoO₃ sample, which included an additional silver layer, showed all these peaks. FESEM observations indicated that the thickness of the samples increased with the longer layering time of the intermediate copper layer. The four-layer structure had the greatest thickness among all samples. After heating, the thickness of the samples increased further.

Keywords: multilayered nanostructures, metal oxide/metal/metal oxide, magnetic sputtering, structural features, morphology

1.Introduction

Transparent conducting oxides (TCO) are binary or ternary compounds containing one or two metallic elements. Their wide bandgap, which can be more than 3eV, makes their specific resistance as low as $10^{-4}\Omega\cdot\text{cm}$ and their extinction coefficient (k) in the range of visible light can be less than 0.001. This remarkable combination of conductivity and transparency is usually impossible in oxides of intrinsic elemental proportions. Badiker discovered that CdO thin films have such properties. Later, Huck showed ZnO, SnO₂, In₂O₃ thin films and their alloys are also TCO. The impurity of these oxides improved electrical conductivity without destroying their optical transmission. Zinc oxide doped with aluminum (AZO), indium oxide doped with tin (ITO), antimony (ATO) or fluorine (FTO) are among the TCO thin films that are used in modern technology. In particular, ITO is widely used.

Actual and potential applications of TCO thin films include (1) transparent electrodes for flat screen monitors (2) transparent electrodes for photovoltaic cells (3) low emissivity windows (4) transparent thin film transistors (5) light emitting diodes and (6) semiconductor lasers. Since the usefulness of TCO thin films depends on their optical and electrical properties, both parameters should be considered along with environmental stability, abrasion resistance, electronic work function, substrate compatibility and other components of a given component. The availability of raw materials and the cost-effectiveness of the preparation method are also important factors in choosing the most suitable TCO material.

Flexible electronic and photonic components on lightweight substrates are new technological and scientific challenges for next-generation applications. There are many reasons for developing technologies in this direction. First, reducing component weight is of fundamental importance in reducing energy consumption. The second reason is related to the crisis of raw materials and the scarcity of some materials involved in the construction of the device, such as In, Ge, Sb, rare earth, etc. If an alternative or a solution to reduce its consumption is not found, the depletion of the very limited resources of indium on earth will soon lead to a crisis in this field. Alternative indium-free oxide/metal/oxide multilayer structures that have been studied so far are: ZnO/Metal/ZnO AZO/metal/AZO,

TiO₂/Metal/TiO₂

NTO/metal/NTO (NTO is titanium doped with niobium)

NiO/Metal/NiO

Bi₂O₃/ Metal/Bi₂O₃

MoO_x/Metal/MoO_x

SnO₂/Metal/SnO₂, which the interlayer metal is generally Au or Ag.

2. Experimental methods

In order to preparing the samples, at first, the glass substrates were placed in a flask containing distilled water and acetone in a ratio of 2:1 for 10 minutes, and the temperature of the hot plate was slowly raised to the boiling point of the solution, and then using the deionized water, it was placed in an ultrasonic machine for 20 minutes, then we dried them using high purity nitrogen gas. We used a double cathode DC/RF mechantron sputtering machine to make three and four layer structures. Before each layering, the device reached the initial vacuum up to the order 5×10^{-5} Torr by the turbomolecular pump. Then the working pressure was adjusted around 7×10^{-3} Torr. Before the layering process, we covered the glass substrates with a shutter and flashed argon gas three times inside the chamber to remove any possible oxygen and pollutants of the chamber. The power was 100 RF and the layering process of the MoO₃ layer was done on the glass substrates. Then without breaking the vacuum, using the second target, the copper metal layer was applied in the first sample for 50 seconds, in the second sample for 100 seconds and in the third sample for 150 seconds. In the last step, again without vacuum, the third layer of MoO₃ was layered on the copper layer. In the case of the four-layer structure, after the layering of the lower layer of MoO₃, silver layer was layered for 30 seconds, then the copper layer was layered for 70 seconds, and finally the upper layer of MoO₃ was layered. After layering and preparation, the samples were annealed in a vacuum oven at 400°C for one hour in order to improving their properties. The X-ray diffraction patterns of the samples were recorded using a D8- Advance Bruker diffractometer equipped with a Cu-Ka anode in the angular range of $2\theta=10-80$. The morphology of the obtained materials was investigated with a ZEISS FE-SEM field emission scanning electron microscope.

3. Results and Discussions

3-1. XRD analysis

Figure 1 shows the XRD diagrams of the three-layer $\text{MoO}_3/\text{Cu}/\text{MoO}_3$ structures and the four-layer $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ structure after annealing at 400°C for 1 hour, obtained from the X-ray diffraction spectrometer of Damghan University, the model D8-Advance Bruker $\text{Cu K}\alpha 1$. As it can be seen, the first sample with 50 seconds of copper metal layering did not show any peaks and it has an amorphous structure. In the second sample, several peaks can be seen at the approximate angles of $97/11^\circ$, $49/23^\circ$, $11/26^\circ$, $89/28^\circ$, $76/36^\circ$ and $58/53^\circ$, which are related to the orthorhombic phase $\alpha\text{-MoO}_3$ with reference code JCPDS=05-0508. These peaks are related to crystal plates with Miller indices (020), (110), (040), (021), (041) and (211), respectively. In addition to these six peaks, two other peaks are also observed at the angles of $06/16^\circ$ and $21/19^\circ$, which corresponds to crystal plates with Miller indices (110) and (200) of the hexagonal MoO_3 phase with the reference code JCPDS-21-0569. All these peaks are also observed in the third sample, with the difference that the intensity of the peaks has increased. In the case of the fourth sample, which has a four-layer structure and a layer of silver metal in addition to copper metal, all these peaks are observed, with this difference that the intensity of most peaks has changed compared to the third sample.

The crystal size of the crystalline samples was calculated using the Debye Scherer's relationship as follows:

$$D = \frac{k\lambda}{\beta \cos \theta}$$

In this regard, λ is the x-ray wavelength of xrd, β is the total width at half of maximum height, θ is the diffraction angle and k is a Scherer constant or shape factor. Considering that the first sample with 50 seconds copper metal layering has an amorphous structure and does not have any diffraction peaks, it is not possible to measure the crystal size for this sample. The crystal size for samples with 100 seconds and 150 seconds of copper metal layering was found to be 2/38 nm and 6/26 nm. For the four-layer sample, the crystal size was 5.31 nm.

3-2. FESEM analysis

Figure 2 shows the cross-sectional images of the $\text{MoO}_3/\text{Cu}/\text{MoO}_3$ three-layer structures with different interlayer layering time and the $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ four-layer structure before annealing, which were taken with a scanning electron microscope (FESEM), the model Zeiss Sigma of Shahrood University. In the same layering condition, the thickness of the MoO_3/Cu (50 s)/ MoO_3 sample was estimated equal to 85 nm, the MoO_3/Cu (100 s)/ MoO_3 was estimated to 234 nm, the MoO_3/Cu (150 s)/ MoO_3 was estimated equal to 340 nm and the $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ was estimated equal to 424 nm. As can be seen in the case of the three-layer structures, the thickness of the structure increased with the increase in the duration of the interlayer copper layering. Also, the four-layer structure has the largest thickness among all samples.

4. Conclusion

In this study, the $\text{MoO}_3/\text{Cu}/\text{MoO}_3$ three-layer structures with different thicknesses of the interlayer copper metal as well as the $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ four-layer structure were prepared on glass substrates by magnetron sputtering and the optical, structural and the electrical properties of these structures were investigated. In all samples, the thickness of the MoO_3 layers was constant and equal to 50 nm. The duration of the copper metal layering was 50 seconds in the first sample, 100 seconds in the second sample, and 150 seconds in the third sample. Also, in the four-layer structure, in addition to the copper metal, a layer of silver metal was added to the structure. In this sample, the duration of silver metal layering was 30 seconds and copper metal was 70 seconds. Also, the changes of the mentioned properties were studied under annealing at 400 degrees Celsius for one hour and the changes of their characteristics were compared with the samples before annealing. According to the XRD results, the

MoO₃/Cu/MoO₃ sample with 50 seconds of copper metal layering showed an amorphous structure. The structures of the other three layers with 100 and 150 seconds of copper layering had peaks corresponding to the orthorhombic phase α -MoO₃ and the hexagonal phase MoO₃, which the intensity of these peaks increased with the increase in the layering time of the interlayer. All of these peaks were also observed in the MoO₃/Ag/Cu/MoO₃ four-layer sample which included an additional layer of silver metal.

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Investigation the Electrical and Optical Properties of $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ Multilayer nanostructures

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Abstract

In this article, the optical and electrical properties of the $\text{MoO}_3/\text{Cu}/\text{MoO}_3$ transparent conductive electrodes and a four-layer transparent conductive electrode $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ prepared by magnetron sputtering on glass substrates was investigated. The results of the optical properties showed that with the increase in the layering time and thickness, the transmittance in the copper layer and the addition of a silver layer decreased. The four-layer structure showed the lowest transmittance. Emissivity with increasing time of copper metal layering, emissivity for the sample with 50 seconds of copper layering reduced to 281/0 and for the sample with 100 seconds of copper layering reduced to 122.0 and for the sample with 150 seconds of copper layering decreased to 104.0. In the end, the competency coefficient with increasing the time of copper metal layering was obtained as 0.24 for the sample with 50 seconds of copper layering, 0.053 for the sample with 100 seconds of copper layering, and 0.064 for the sample with 150 seconds of copper layering. Before heating, the three-layer sample with 50 seconds of copper layering had the highest reflectance. By increasing the duration of the copper layering, the reflection decreased. After heating, the sample with 100 second metal layering showed the highest reflectance. The four-layer structure with two middle layers of copper and silver metal had the lowest reflectivity both before and after heating compared to all samples. Based on the electrical measurements, the resistance of the samples decreased with the increase in the duration of the interlayer metal layering. Energy gap was obtained as 17.3 eV for the sample MoO_3/Cu (50 s)/ MoO_3 , 38/3 eV for the sample MoO_3/Cu (100 s)/ MoO_3 , 82/2 eV for the sample MoO_3/Cu (150 s)/ MoO_3 and 18/3 eV for sample $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$. Also, the energy gap of the samples after annealing was obtained 51/2 eV for the sample with 50 seconds of copper layering, 41.3 eV for the sample with 100 seconds of copper layering, 43.3 eV for the sample with 150 seconds of copper layering and 34.3 eV for the $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ four-layer structure.

Keywords: metal oxide/metal/metal oxide, magnetic sputtering, optical properties, electrical properties

1. Introduction

Transparent conductive electrodes (TCEs) are important parts in various light components such as touch screens, solar cells and light-emitting diode(LED). They provide the electrical conductivity and optical transparency for effective charge transfer and optical transmission, respectively. Among the different types of TCEs, three-layer TCEs based on metal oxide/metal/metal oxide structures have attracted the attention of researchers due to their excellent electrical and optical properties. MO/M/MO TCEs show excellent electrical conductivity and optical transparency due to the combination of metal and metal oxide layers. The metal oxide layers act as conductive layers, while the metal layer in the middle acts as a contact and works with low resistance between two oxide layers. The selection of metal oxide materials is very important to achieve high electrical conductivity and optical transparency, because different metal oxides have different energy gap and mobility of electrons, and determine

the optical and electrical properties of material. The most common metal oxide used in TCEs is ITO, which has high conductivity and an energy gap about 6.3 eV, which makes it transparent in the visible region. Other similar metal oxides such as ZnO and TiO₂ have also been used in TCE, but they usually have a lower electrical conductivity and a higher energy gap than ITO. The metal layer in the middle of MO/M/MO TCEs creates low electrical resistance that causes effective charge transfer across the electrode. The choice of metal for this layer depends on factors such as cost, compatibility with metal oxide layers, and favorable electrical properties. The metal layer in the middle of the MO/M/MO electrode can be made of different metals such as silver (Ag), gold (Au) and copper (Cu) due to its low resistance and compatibility with different metal oxides. The choice of metal depends on factors such as cost, compatibility with metal oxide layers, and favorable electrical properties. The optical and electrical properties of a three-layer MO/M/MO transparent conductive electrode can be improved by controlling the thickness of each layer and the preparation conditions of layers. For example, increasing the thickness of the metal layer can reduce the surface resistance, while increasing the thickness of the metal oxide layers can improve the optical transparency. Despite its advantages, the MO/M/MO electrode structure also has some limitations. For example, the use of rare and expensive materials, such as indium for ITO, can make the production of electrodes expensive on a large scale. In addition, the metal layer in the middle of the electrode can be exposed to oxidation and corrosion, which leads to the destruction of the electrical properties of electrode over time. In general, the MO/M/MO electrode structure is a type of transparent conductive electrode widely used in electronic components. As research continues to discover new materials and manufacturing techniques, it is likely that further improvements and innovations will be made to increase the performance and cost-effectiveness of MO/M/MO electrodes. The high reflectivity of infrared waves is another advantage of transparent conductive oxides, which has led to use of these electrodes as insulating layering to conserve energy. Until now few studies on MoO₃/Cu/MoO₃ structures has been carried out and no study has been carried out in the field of investigating their emissivity and reflectivity in the infrared region on the mentioned structure. Therefore, one of our goals in this research is studying and investigating the optical, electrical, and thermal characteristics and calculate the emissivity and competency coefficient of these structures.

2. Experimental methods

A thin layer of MoO₃ is layering on a glass substrate using radio frequency sputtering with a thickness of 50 nm. The layering process started with MoO₃ (purity 99/99%) with diameter, thickness and RF power as 2 inch, 6 mm and 80 W, respectively. The distance between the substrate and the target is 75 mm. A thin layer of Ag and Cu were layering at normal flux angle with layering times of 30 and 70 seconds respectively using DC power and annealed at a temperature of 400 ° C. Before each layering, the pressure the chamber is reduced up to the order of 2×10^{-3} Torr, and in order to clean the surface of the copper, silver and MoO₃ targets, they are dispersed for 5 minutes before the main layering.

In this study, a four-point resistance probe has been used to calculate the surface resistance and Windows computer software has been used to check the thermal characteristics of the samples, determine the heat transfer rate and simulate the low-emissivity double-wall systems covered with each of our samples.

3. Results and discussion

3-1. Calculation the reflection and transmission coefficients

The transmission spectrum of each of samples in the wavelength range of 300-1100 nm is shown in Figure 1. As can be seen in this figure, the amount of transmission of the samples before annealing in the visible area is relatively reduced by increasing the duration of the copper metal layering and also adding silver metal as the middle layer. In the case of samples after annealing, a more regular behavior is observed for each sample in the wavelength range. In these samples, the transmission rate decreases with the increase in the duration of the copper metal layering. Also, the sample with silver layer has the lowest transmission rate. Considering the importance of the transmission rate in the region of 400-800 nm, T_{av} was calculated for each sample and reported in Table 1.

According to this table, almost a decreasing trend is observed with increasing the duration of the copper metal layering and also adding the silver layer.

Until today, few studies have been conducted on the reflectance of three-layer $\text{MoO}_3/\text{Cu}/\text{MoO}_3$ electrodes in the infrared region before and after annealing. Reflectance in the infrared region is one of the most important parameters of these electrodes for industrial usage. In this study, the reflection of these electrodes in the infrared region, before and after annealing, for use in low emissivity layering, has been investigated for the first time. The reflection spectrum of each sample in the wavelength range of 400-1800 nm is shown in Figure 2. According to Figure 2-a, it can be seen that before annealing at 400°C , the three-layer sample with 50 seconds of copper metal layering has the highest reflectivity compared to other samples. By increasing the duration of copper metal layering, the amount of reflection decreases. Also, the four-layer structure has the lowest amount of reflection compared to other samples. As can be seen in Figure 2-b, after annealing, the sample with 100 seconds of copper metal layering has the highest reflectivity compared to other samples, followed by the sample with 150 seconds of copper layering. In the case of these samples, like the samples before annealing, the four-layer sample with two middle layers of copper and silver metal has the lowest reflectance. The average amount of transmission and reflection in the solar (wavelength range) and infrared regions are reported in Table 2.

Using the data obtained from the transmission and reflection spectrum of $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ samples before and after annealing shown in figures 2a and 2b, their transmission and reflection coefficients in the solar (1700-250 nm), visible (800-400 nm) and infrared (1700-800 nm) regions were calculated using equation 2 and presented in Table 1.

where $V(\lambda)$ is the spectral efficiency and $T(\lambda)$ and $R(\lambda)$ are the transmission percentage and the reflection percentage in a certain wavelength, respectively.

Considering that the amount of transmission in the visible region and the amount of reflection in the infrared range for the MoO_3/Cu (50 s)/ MoO_3 sample is higher than the sample before annealing, this sample can be more desirable for the purpose of energy conservation and as thermal insulation coatings.

3-2. Calculation the width of energy band

The width of the energy band of the samples was calculated using Tauc's relation. E_g was calculated by extrapolating the linear part of the curves until zero absorption, that is, where $\alpha h\nu$ becomes zero. Figure 3 shows the changes of band gap of the samples before and after annealing, respectively. According to Figure 3, the band gap was obtained equal to 17.3 eV for sample MoO_3/Cu (50 s)/ MoO_3 , 38/3 eV for the sample MoO_3/Cu (100 s)/ MoO_3 , 82/2 eV for the sample MoO_3/Cu (150 s)/ MoO_3 and 18/3 eV for the sample $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$. Also, according to Figure 3, the bandgap of the samples after annealing is equal to 51.2 eV for the sample with 50 seconds of copper layering, 41.3 eV for the sample with 100 seconds of copper layering, and 43.3 eV for the sample with 150 Second of copper layering and it was obtained equal to 34.3 eV for the four-layer $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ structure.

3-3. Calculation the surface resistance

When the thickness of the metal layer is very small, the layer is formed in the form of islands separated from each other and with large distances. By increasing the thickness of the metal layer, the distance between islands decreases, and then a continuous layer of metal is formed, and the conductivity of the structure increases. Studies showed that the growth of a thin layer of metal on the layer MoO_3 follows the Volmer-Weber model. Based on this model, the different conductivity of the samples depends on the thickness of the metal in the middle of the three-layer structures. In cases where metallic films are discontinuous and have islands, there is a different resistance model in which Quantum tunneling, metal conduction and metal oxide conduction are involved. In such a conditions, metal surface layering determines whether quantum tunneling plays the main role in determining the conductivity or metal oxide conductivity. For example, in the case of small metallic islands with

large free space between them, the role of metal oxide is dominant in conductivity. However, the expansion of the islands reduces the space and the islands begin to combine with each other, forming a continuous layer. In this condition, quantum tunneling plays a conductive role. In general, in the presence of larger islands with small gaps, quantum tunneling occurs while in continuous films, bulk conduction occurs.

The overall surface resistance of multilayer structures can be calculated from the following equation:

Considering that the resistance of molybdenum oxide is higher than the copper, the resistance of the prepared three-layer metal oxide/metal/metal structures depends on the metal resistance. Based on the measurements, the resistance of the MoO_3/Cu (50 s)/ MoO_3 sample was obtained equal to $25 \Omega/\text{sq}$, that by increasing the copper layering time to 100 and 150 seconds, the resistance reduced to $10 \Omega/\text{sq}$ and $5/8 \Omega/\text{sq}$, respectively for samples MoO_3/Cu (100 s)/ MoO_3 and MoO_3/Cu (150 s)/ MoO_3 . Also, the resistance value of the sample MoO_3/Cu (50 s)/ MoO_3 was obtained equal to $1.4 \Omega/\text{sq}$. Also, annealing the sample at a temperature of 400 degrees has reduced the resistance and then improved the electrical and thermal properties.

3-4. Calculation of emissivity

Electromagnetic waves can pass, absorb or reflect from the surface of a material. The ability of a material to radiate infrared energy is called emissivity, and materials with low emissivity have more favorable conditions for use as building glass coating. Building products usually emit or radiate heat in the form of infrared wave energy. Reducing the heat emission of the product can greatly improve its insulation properties. Emissivity is the ratio of the energy radiated from the surface of a material to the energy radiated from a perfect emitter called as black body at the same temperature and wavelength and under the same conditions. This is a dimensionless number between zero (for a perfect reflector) and one (for a perfect radiant). Using windows with low emission prevents the transfer of energy from outside to inside the building and preserves the thermal/cooling energy.

The emissivity depends on the surface resistance and can be calculated with the following equation:

This equation for samples with $Z_0 \gg R_{sh}$ (Vacuum impedance = 377 Ohms) and at a wavelength of $\lambda > 3$ micrometers, is obtained from the following equation:

Transparent conductive electrodes with low emissivity, thin, colorless and non-toxic characteristics are applied on building window glass to improve energy efficiency. These windows are completely safe and are becoming the standard for energy efficiency in modern homes. Low-emission electrodes applied to windows prevent the penetration of infrared waves into the glass from the outside environment. In addition, these low-emissivity coatings maintain thermal/cooling energy. The results of emissivity for all samples are shown in Table 3. Due to the dependence of the emissivity on the surface resistance and the minimal resistance of the sample $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$, its value for this sample is low and equal to 104.0. A low amount of emission means a reduction in the passage of heat and infrared waves. The property that makes the material a desirable layering for high reflection of infrared waves and heat insulation. Until now, no study has been done on determining the emissivity value of the three-layer $\text{MoO}_3/\text{Ag}/\text{Cu}/\text{MoO}_3$ structures.

3-5. Calculation of competency coefficient

Because both conductivity and transparency parameters are very important in industry, the competency parameter is used to better comparing the properties of three-layer metal oxide/metal/metal oxide electrodes. The higher the competency coefficient, the better transparent conductive electrode we will have. The competency coefficient of the prepared samples was calculated using the following equation.

The competency coefficient values of the samples are given in Table 4. According to the mentioned values, the highest competency coefficient was obtained for the sample with 150 seconds of copper metal layering equal to $0.064 \Omega^{-1}$. The competency coefficient of the sample with 100 seconds of copper metal layering was equal to $0.053 \Omega^{-1}$ and the competency coefficient of the sample with 50 seconds of copper metal layering was equal to

024.0 Ω^{-1} . Therefore, with the increase in the duration of the copper metal layering and the increase in the thickness of this layer, the competency coefficient also increased.

4. Conclusion

The thickness of the samples increases with the increase in the duration of the copper metal layering. The highest thickness was related to the four-layer structure. The transmission rate of samples decreased by increasing the duration of the copper layering and adding a silver layer. The lowest rate of transmission was related to the four-layer structure. Before heating, the three-layer sample with 50 seconds of copper layer had the highest reflectance. By increasing the duration of the copper layering, the reflection decreases. After heating, the sample with 100 seconds of copper layering showed the highest reflectance. The four-layer structure with two middle layers of copper and silver metal had lower reflectivity both before and after heating compared to all samples. Emissivity with increasing time of copper metal layering, emissivity for the sample with 50 seconds of copper layering reduced to 281.0 and for the sample with 100 seconds of copper layering reached to 122.0 and for the sample with 150 seconds of copper layering decreased to 104.0. In the end, the competency coefficient with increasing the time of copper metal layering was obtained equal to 024.0 for the sample with 50 seconds of copper layering, equal to 053.0 for the sample with 100 seconds of copper layering, and equal to 064.0 for the sample with 150 seconds of copper layering. Regarding the electrical properties, the resistance of the samples decreased with the increase in the duration of the middle metal layering.

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The effectiveness of lifestyle education based on Choice Theory in reducing procrastination and maladaptive or dysfunctional perfectionism

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ABSTRACT

The aim of the present study is to evaluate the effectiveness of lifestyle education based on Choice Theory in reducing procrastination and maladaptive or dysfunctional perfectionism. For this purpose, a sample of 60 individuals was tested, with 20 participants assigned to the control group, 20 to the procrastination test group, and 20 to the maladaptive perfectionism test group. It should be noted that the content of the lifestyle education sessions was based on Choice Theory. To measure procrastination, the Tuckman Procrastination Scale (TPS) was used, and to assess perfectionism, the Hill Perfectionism Questionnaire was employed. The results indicate that lifestyle education based on Choice Theory leads to a reduction in both procrastination and maladaptive or dysfunctional perfectionism across various age groups and conditions.

Keywords: lifestyle, Choice Theory, procrastination, perfectionism

INTRODUCTION

Procrastination refers to the unnecessary postponement of tasks, without any valid reason for delaying them. A procrastinator is aware that putting off a task can have negative consequences, yet they still delay it. On the other hand, procrastination can be described as prioritizing activities that are more pleasurable or less painful to complete, regardless of their importance or necessity. Often, procrastination is viewed merely as a challenge in goal-setting and planning. However, the negative consequences of procrastination extend far beyond these aspects. Multiple studies have shown that procrastination can create stress for an individual and pose a threat to their health. Procrastinators tend to have weaker immune systems and are more susceptible to illness. Symptoms of depression, feelings of guilt, and insomnia are more common among them compared to others. Today, the "negative impact of procrastination on health" is recognized and confirmed. Procrastinating on tasks and delaying responsibilities is a complex behavior and can result from a combination of various causes. Those who favor Freud's psychoanalytic approach often consider anxiety to be the root of many procrastinations. They believe that if you feel anxious about completing a task, you are likely to put it off. But how does this anxiety arise? From various causes. For example, if a student expects their project to definitely get an A, completing the project is likely to be anxiety-inducing for them. Therefore, compared to another student who is willing to accept a B, they are more likely to postpone completing the project. Regardless of the Freudian approach, numerous studies have confirmed that "fear of failure" can be one of the roots of procrastination. Some psychologists also believe that the family environment during childhood and the behavioral and educational methods of parents can be one of the roots of procrastination. For example, parents who strictly control their children and set many do's and don'ts for them, or who expect their children to perform tasks flawlessly, might raise procrastinating children. Children who feel they have no control over deciding whether to do or not do tasks might choose procrastination as a form of rebellion and self-expression. Alternatively, high standards and perfectionism can drive them toward procrastination.

Perfectionism is a personality variable characterized by traits such as striving for perfection, setting very high standards for behavior, and engaging in self-critical evaluations. The concept of perfectionism refers to self-destructive thoughts and behaviors aimed at achieving extremely unrealistic and excessive goals. Perfectionism is essentially an irrational belief individual have about themselves and their surroundings. Perfectionists believe that they and their environment must be perfect, and that any effort in life must be without mistakes or errors. Perfectionists often anticipate and fear rejection or criticism from others. This fear leads them to adopt a defensive stance against criticism, causing them to disappoint and distance themselves from others. Today, researchers divide perfectionism into two categories: positive and negative. Positive perfectionism refers to behaviors and cognitions that drive individuals to achieve high-level goals and desired outcomes, stimulated by positive reinforcement and a growth orientation. In contrast, negative perfectionism involves behaviors and cognitions aimed at achieving high-level goals and avoiding negative outcomes, stimulated by negative reinforcement and fear of failure.

The negative aspect of perfectionism is associated with high self-criticism, which manifests as more severe negative reactions and a diminished sense of control over conditions when faced with stress. This feeling of lack of control over circumstances is accompanied by negative affect, leading to the development of maladaptive emotion regulation strategies.

In fact, individuals with high levels of perfectionism are often their own harshest critics, believing that they are never good enough. Consequently, they become trapped in a never-ending cycle of excessive effort. These individuals strive for flawlessness and set criteria for the highest level of performance, characterized by critical self-evaluations and concerns about others' assessments.

The World Health Organization defines quality of life as the extent to which individuals perceive their situation in life in terms of cultural values, goals, expectations, standards, and life priorities. Lifestyle modification aims to address behaviors impacting overweight, such as physical activity and psychological dimensions. Lifestyle modification focuses on raising awareness about habits and engaging in activities that improve them, modifying and controlling effective stimuli, and expanding principles and techniques to manage inappropriate and irresponsible behaviors.

Therefore, training that can correct individuals' thoughts and behaviors can be effective in improving the efficacy of lifestyle modification. One therapeutic approach that has recently gained attention in the country is Choice Theory. This approach, developed by William Glasser, posits that humans choose behaviors to satisfy their five basic needs: physiological needs, power and achievement, belonging, freedom, and fun. Consequently, individuals are responsible for their choices. According to Glasser, behavior consists of four aspects: thinking, acting, feeling, and physical changes, with feelings and physical changes being influenced by thoughts and actions. Thus, individuals' choices will have different consequences.

Given the information provided, this study aims to examine the effectiveness of lifestyle education based on Choice Theory in reducing procrastination and maladaptive or dysfunctional perfectionism.

RESEARCH BACKGROUND

Article [17] argues that from the perspective of mood regulation, procrastination increases the risk of procrastination in stressful contexts, as stressors deplete coping resources and lower the threshold for tolerating negative emotions. Drawing on insights from coping theory and emotion regulation, the new model of stress-context vulnerability to procrastination suggests that the risk of procrastination increases in stressful contexts primarily because procrastination is a low-resource means of avoiding the negative and difficult emotions associated with the task. Article [18] identified the social, cultural, organizational, and contextual factors that may reinforce or facilitate task procrastination (such as excessive freedom in study situations, long deadlines, temptations, and distractions),

documenting their research basis and offering recommendations for modifying these factors to reduce and prevent procrastination. We argue that greater attention to such procrastination-friendly factors in academic environments is crucial, and relatively minor measures to mitigate their harmful effects may bring significant benefits to students, institutions, and society. Article [19] assessed the relationship between procrastination and subsequent health outcomes among university students in Sweden. The conclusions of this cohort study on Swedish university students show that procrastination is associated with subsequent mental health problems, disabling pain, unhealthy lifestyle behaviors, and worse psychosocial health factors. Given that procrastination is common among students, these findings may be important for improving understanding of student health. Article [20] provided a review focused on students, residents, and medical practitioners, aimed at a) determining the levels of perfectionism and the prevalence of the impostor phenomenon, and b) examining the relationship between perfectionism, impostor phenomenon, and mental health. Medical students had similar perfectionism scores to other student groups but scored lower on maladaptive perfectionism. The overall prevalence of the impostor phenomenon ranged from 22.5% to 46.6%. More women (41%-52%) experienced clinical levels of the impostor phenomenon compared to men (23.7%-48%). Most studies found no association between the impostor phenomenon and the academic year of training. Both personality traits were associated with negative mental health outcomes. The culture of medicine can teach and/or exacerbate these traits and influence the formation of professional identity. Both traits contribute to the distress of learners throughout the common educational practices in medical training. Comprehensive changes in medical education that consider the relationship between the culture of medicine, professional identity formation, the impostor phenomenon, and perfectionism are needed. Longitudinal studies can help identify the implications of these findings for professional identity formation and medical education. Article [21] examined the effectiveness of self-help and face-to-face CBT for perfectionism in reducing perfectionism, anxiety, depression, and eating disorders. In total, 15 randomized controlled trials of CBT for perfectionism were identified ($N = 912$ participants; mean combined age = 23 years) that met the inclusion criteria. Medium or large effect sizes were found for perfectionism measures. Personal standards ($g = 0.57$, 95% CI = 0.43-0.72), concern over mistakes ($g = 0.89$, 95% CI = 0.71-1.08), and clinical perfectionism ($g = 0.87$, 95% CI = 0.70-1.04). Moderate effects were found for eating disorder symptoms ($g = 0.61$, 95% CI = 0.36-0.87) and depression ($g = 0.60$, 95% CI = 0.28-0.91), with a small to medium effect on anxiety ($g = 0.42$, 95% CI = 0.21-0.62). No publication bias was found. Limitations included the small number of included trials and the lack of active treatment comparisons. Results indicated that CBT for perfectionism is effective in reducing perfectionism and symptoms of depression, anxiety, and eating disorders. Future research should explore comparisons of CBT for perfectionism with other psychological treatments. Article [22] examined the relationship between child and parent perfectionism, seeking to test the empirical support for the social learning model and the social expectations model, as well as children's perceptions of parenting styles. The present study involved 119 children (51.2% girls, $M_{age} = 11.67$ years) and their parents. Data were collected through multiple self-report measures. The results indicated relationships between most identical dimensions of parent and child perfectionism, thus providing supportive evidence for the social learning model. In terms of the role of gender in the transmission of perfectionism, fathers' observed perfectionism was only associated with sons' perfectionism, while mothers' perfectionism was associated with daughters' perfectionism. Our findings allow for a deeper understanding of the role of authoritarian parenting style perception in developing maladaptive perfectionism. Parenting styles perceived by both mother and father contributed more to daughters' perfectionism than to sons' perfectionism. The results contribute to the understanding of the role of parental factors in the development of perfectionism.

RESEARCH METHODOLOGY

In this study, preliminary and foundational information was gathered through library research. Additionally, analytical data were collected via questionnaires. A sample of 60 individuals was considered as the research population, divided into three groups: 20 individuals in the control group, 20 individuals in the procrastination test group, and 20 individuals in the perfectionism test group. The content of the lifestyle training sessions based on the Choice Theory approach was conducted as outlined in Table 1.

To measure the level of procrastination, the Tuckman Procrastination Scale (TPS), developed by Tuckman in 1991, was used. This questionnaire consists of 16 questions, with responses rated on a four-point Likert scale ranging from "Certainly Not True of Me" to "Certainly True of Me."

To assess perfectionism, Hill's Perfectionism Questionnaire was utilized. This questionnaire was created in 2004 by Hill and colleagues and measures individuals' levels of perfectionism. It consists of 59 questions, with answers on a four-point Likert scale ranging from "Strongly Agree" to "Strongly Disagree." The questionnaire includes components such as interpersonal sensitivity, striving for excellence, organization, perceived parental pressure, purposefulness, and high standards for others.

Table 1 - Content of Lifestyle Training Sessions Based on the Choice Theory Approach

SESSIONS OBJECTIVES

First	Introduction, establishing a therapeutic relationship, identifying goals, explaining the Choice Theory approach, completing the first assessment, explaining homework assignments.
Second	Teaching the Choice Theory approach: Reviewing methods of presenting behaviors and discussing the reasons for selecting certain behaviors, including choices related to these behaviors, and providing homework assignments.
Third	Teaching topics related to physical health, proper sleep, and nutrition, as well as improving relationships and applying techniques related to homework assignments.
Fourth	Teaching topics related to physical activity, exercise, and relaxation, along with applying techniques related to homework assignments.
Fifth	Teaching techniques and methods related to self-control and emotion regulation through the Choice Theory approach, including homework assignments.
Sixth	Teaching techniques and methods related to thought and behavior management through the Choice Theory approach, including homework assignments.
Seventh	Teaching techniques and methods related to emotion and behavior management through the Choice Theory approach, including homework assignments.
Eighth	Teaching communication and problem-solving skills through the Choice Theory approach, creating a sense of motivation and preparing individuals for challenges, including homework assignments.
Ninth	Summarizing and reviewing the members' questions and answers, implementing final evaluations, and conducting group activities.

RESEARCH FINDINGS

Based on the descriptive analysis of the participants' results, the age distribution and educational levels of the participants are categorized as follows:

- **Age Groups:** 25-35, 35-45, 45-50
- **Educational Levels:** Diploma, Bachelor's, Master's, PhD

The distribution for each group is as follows:

- **Control Group:**
 - Age: 8 participants aged 25-35, 8 participants aged 35-45, 4 participants aged 45-50
 - Education: 6 participants with a Diploma, 9 with a Bachelor's, 3 with a Master's, 2 with a PhD

- **Procrastination Test Group:**
 - Age: 5 participants aged 25-35, 8 participants aged 35-45, 7 participants aged 45-50
 - Education: 3 participants with a Diploma, 9 with a Bachelor's, 5 with a Master's, 3 with a PhD
- **Perfectionism Test Group:**
 - Age: 8 participants aged 25-35, 4 participants aged 35-45, 8 participants aged 45-50
 - Education: 5 participants with a Diploma, 10 with a Bachelor's, 2 with a Master's, 3 with a PhD

Participants - Control Group: The participants in the control group are distributed across different age and education levels, providing a balanced representation for comparison with the test groups.

Here is the detailed breakdown based on the provided specifications:

Characteristic	Description	Number of Participants
Age	25-35	8
	35-45	8
	45-50	4
Education	Diploma	6
	Bachelor's	9
	Master's	3
	PhD	2

Here is the detailed breakdown for the Procrastination Test Group participants:

Characteristic	Description	Number of Participants
Age	25-35	5
	35-45	8
	45-50	7
Education	Diploma	3
	Bachelor's	9
	Master's	5
	PhD	3

Here is the breakdown for the Perfectionism Test Group participants:

Characteristic	Description	Number of Participants
Age	25-35	8
	35-45	4
	45-50	8
Education	Diploma	5
	Bachelor's	10
	Master's	2

Characteristic	Description	Number of Participants
	PhD	3

Normality Test: To determine the distribution of the data, the Kolmogorov-Smirnov test was applied. The research data includes results from the procrastination scale, interpersonal sensitivity, striving for excellence, organization, perceived parental pressure, purposefulness, and high standards for others. The results of the test indicate that the significance values (sig) for these scales were greater than 0.05. Given these values, we can conclude that the data follows a normal distribution. Therefore, parametric tests can be used to analyze the data.

Kolmogorov-Smirnov Test Results for Participants:

Variable	Kolmogorov-Smirnov Test Result (sig)
Procrastination	0.846
Interpersonal Sensitivity	0.364
Striving for Excellence	0.825
Organization	0.576
Perceived Parental Pressure	0.535
Purposefulness	0.537
High Standards for Others	0.509

These results indicate that all variables have significance levels (sig) greater than 0.05, confirming that the data follows a normal distribution. Therefore, parametric tests are suitable for further data analysis.

QUESTIONNAIRE RELIABILITY:

To assess the reliability of the questionnaire, Cronbach's Alpha test was used. The criterion for reliability in this test is achieving a minimum score of 0.7. The Cronbach's Alpha results for the variables in the questionnaire are as follows:

Variable	Cronbach's Alpha
Procrastination	0.82
Interpersonal Sensitivity	0.88
Striving for Excellence	0.72
Organization	0.75
Perceived Parental Pressure	0.78
Purposefulness	0.89
High Standards for Others	0.93

With Cronbach's Alpha values ranging from 0.72 to 0.93, the questionnaires used in this research demonstrate acceptable and strong reliability. All values meet or exceed the threshold of 0.7, indicating that the instruments are consistent and reliable for measuring the intended variables.

PEARSON CORRELATION ANALYSIS

In this section, the correlation analysis between the variables has been analyzed to measure the significance of the relationship between the variables.

Correlation of Research Variables

Variable	Abbreviations
Procrastination	Z1
Interpersonal Sensitivity	Z2
Striving for Excellence	Z3
Organization	Z4
Perceived Parental Pressure	Z5
Purposefulness	Z6
High Standards for Others	Z7

In this study, Pearson's correlation test was used to measure the correlation between research variables. According to the obtained results, because the results are higher than the value of 0.5, it can be said that there is a strong correlation between the research variables.

The Result of The Pearson Correlation Test of The Control Group

	Z1	Z2	Z3	Z4	Z5	Z6	Z7
Z1	1						
Z2	0.891	1					
Z3	0.695	0.562	1				
Z4	0.781	0.701	0.516	1			
Z5	0.591	0.900	0.697	0.515	1		
Z6	0.833	0.580	0.680	0.514	0.572	1	
Z7	0.995	0.697	0.678	0.797	0.857	0.020	1

DESCRIPTIVE DATA ANALYSIS

The following table shows the results of the descriptive analysis of the data. According to the obtained results, the values of mean, median, standard deviation and skewness have decreased in the test group. This shows the effectiveness of lifestyle education with the choice theory approach.

Results of Descriptive Data Analysis

Procrastination Test Group				Control Group				Variable
Skewness	Standard Deviation	Median	Mean	Skewness	Standard Deviation	Median	Mean	
0.42	0.01	5.66	5.92	1.87	3.14	9.50	8.13	z1
0.85	0.93	4.93	5.93	1.32	1.94	9.52	9.55	z2
0.82	0.40	6.94	4.39	1.90	2.69	7.82	8.30	z3
0.05	0.23	3.72	4.42	1.26	1.22	7.35	8.30	z4

0.49	0.48	3.90	6.63	0.24	3.94	7.89	9.05	z5
0.51	0.44	6.75	5.43	0.11	3.34	9.49	8.67	z6
0.98	0.52	6.99	4.02	0.39	3.85	8.46	8.74	z7

Perfectionism Test Group				Control Group				Variable
Skewness	Standard Deviation	Median	Mean	Skewness	Standard Deviation	Median	Mean	
1.81	3.05	9.22	7.89	1.93	3.23	9.79	8.37	z1
1.28	1.88	9.23	9.26	1.36	2.00	9.81	9.84	z2
1.84	2.61	7.59	8.05	1.96	2.77	8.05	8.55	z3
1.22	1.18	7.13	8.05	1.30	1.26	7.57	8.55	z4
0.23	3.82	7.65	8.78	0.25	4.06	8.13	9.32	z5
0.11	3.24	9.21	8.41	0.11	3.44	9.77	8.93	z6
0.38	3.73	8.21	8.48	0.40	3.97	8.71	9.00	z7

The results of the correlated t-test show a significant effect of the training program on the research variables in the test group ($P < 0.05$), however, no significant difference was observed in the control group between the pre-test and post-test ($P < 0.05$). In addition, the results of the analysis of covariance test have been presented for comparison between groups. The results of the covariance analysis showed that after controlling for the effect of the pre-test, there was a significant difference in the results of the research variables ($P < 0.05$) in the post-test between the control and test groups; In this way, the amount of research variables in the lifestyle training group with the choice theory approach on reducing procrastination and harmful or inefficient perfectionism had a significant improvement compared to the control group.

Correlated T-Test Results for Intra-Group Comparison of Research Variables in Exercise and Control Groups in Pre- and Post-Test Stages of Procrastination

Procrastination Test Group				Control Group				Variable
P	T	Post Test	Pre-Test	P	T	Post Test	Pre-Test	
0.001	3.32	34.74	41.37	0.185	9.40	46.39	49.51	z1
0.001	5.89	39.74	47.17	0.838	2.22	47.98	50.01	z2
0.001	8.81	34.36	40.38	0.820	-2.70	48.39	50.68	z3
0.001	10.13	33.97	40.41	0.722	5.65	44.94	46.42	z4
0.001	1.32	38.34	44.17	0.767	8.24	43.53	46.48	z5
0.001	10.09	34.51	40.05	0.331	-5.27	38.75	42.24	z6
0.001	3.36	40.39	48.07	0.164	2.55	39.37	42.96	z7

Correlated T-Test Results for Intra-Group Comparison of Research Variables in Exercise and Control Groups in Pre- and Post-Test Stages of Perfectionism

Perfectionism Test Group				Control Group				Variable
Skewness	Standard	Median	Mean	Skewness	Standard	Median	Mean	

	Deviation				Deviation			
0.18	9.12	45.00	48.02	0.19	9.68	47.78	51.00	z1
0.81	2.15	46.54	48.51	0.86	2.29	49.42	51.51	z2
0.80	-2.62	46.94	49.16	0.84	-2.78	49.84	52.20	z3
0.70	5.48	43.59	45.03	0.74	5.82	46.29	47.81	z4
0.74	7.99	42.22	45.09	0.79	8.49	44.84	47.87	z5
0.32	-5.11	37.59	40.97	0.34	-5.43	39.91	43.51	z6
0.16	2.47	38.19	41.67	0.17	2.63	40.55	44.25	z7

The Results of The Covariance Analysis Test to Investigate Lifestyle Education with The Selection Theory Approach on The Research Variables

Eta squared	p	df	F	Group	Test Stage	Variable
0.50	0.001	1	10.46	Control	Post Test	Procrastination
				Anger Management Skills Training Test	Post Test	
				Emotional Intelligence Training Test Group		
				Schema Therapy Test Group		
0.34	0.001	1	8.29	Control	Post Test	Interpersonal Sensitivity
				Anger Management Skills Training Test	Post Test	
				Emotional Intelligence Training Test Group		
				Schema Therapy Test Group		
0.45	0.001	1	18.20	Control	Post Test	Striving for Excellence
				Anger Management Skills Training Test	Post Test	
				Emotional Intelligence Training Test Group		

				Schema Therapy Test Group		
0.72	0.001	1	5.98	Control	Post Test	Organization
				Anger Management Skills Training Test	Post Test	
				Emotional Intelligence Training Test Group		
				Schema Therapy Test Group		
0.32	0.001	1	14.96	Control	Post Test	Perceived Parental Pressure
				Anger Management Skills Training Test	Post Test	
				Emotional Intelligence Training Test Group		
				Schema Therapy Test Group		
0.45	0.001	1	16.54	Control	Post Test	Purposefulness
				Anger Management Skills Training Test	Post Test	
				Emotional Intelligence Training Test Group		
				Schema Therapy Test Group		
0.64	0.001	1	12.31	Control	Post Test	High Standards for Others
				Anger Management Skills Training Test	Post Test	
				Emotional Intelligence Training Test Group		

				Schema Therapy Test Group		
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CONCLUSION

The purpose of the present study is to investigate the effectiveness of lifestyle education with the choice theory approach on reducing procrastination and harmful or ineffective perfectionism. For this purpose, 60 tons were taken as a statistical sample. So that 20 people were considered as the control group, 20 people as the procrastination test group and 20 people as the perfectionism test group. It should be noted that the content of the lifestyle training sessions was done with the choice theory approach. Also, Tackman's Procrastination Questionnaire (TPS) was used to measure procrastination, and Hill's Questionnaire was used to measure perfectionism. According to the selected questionnaires, research variables include procrastination, perception of pressure from parents, interpersonal sensitivity, purposefulness, striving for excellence, order and organization, high standards for others. The results obtained from the covariance analysis test to investigate the lifestyle education with the selection theory approach on the research variables are 10.46, 8.29, 18.20, 5.98, 14.96, 16.54, and 12.31 respectively for each variable. Also, the obtained results indicate that lifestyle education with the choice theory approach reduces procrastination and harmful or inefficient perfectionism in people of different ages and conditions.

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Investigating the Relationship of Dark Tetrad and Emotional Dysregulation in the context of Internet Gaming Disorder. Case study of a high school in Tehran

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ABSTRACT

Playing internet video games are becoming increasingly widespread, yet a minority of people show signs of pathological gaming. This research aims to investigate the relationship between pathological internet gaming, online gaming motives Dark Tetrad traits of personality (Machiavellianism, Psychopathy, Narcissism, and Sadism), and Difficulties in Emotion Regulation. We have identified significant correlations between Internet Gaming Disorder (IGD) and all the mentioned variables and tested their predictive strength using linear regression modelling. The results show that the number of hours spent playing only online games, Dark Tetrad, Emotional Dysregulation, and the gaming motivations had significant correlations with IGD and explained 42% of its variance (however only 'escape' was a significant predictor [Std. $\beta = 0.34$, p -value = 0.005]). Dark Tetrad and Emotional Dysregulation could significantly predict IGD as well (r squared = 0.09 & 0.13). There were intercorrelations between these variables too that could suggest possible indirect mediation pathways.

keywords: Internet Gaming Disorder, Motives for Online Gaming, Dark Tetrad, Emotional Dysregulation

1. INTRODUCTION

With the rising popularity of video games in the recent years [1], the increase in time spent on this leisure activity, and technological advancements that create increasingly more immersive environments, discourses about pathological use of gaming have been growing. Internet Gaming Disorder (IGD), as a pathological form of playing video games, has been added to the International Classification of Diseases (ICD-11) and the research appendix of Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [2] & [3]. However, the diagnosis and perception of 'pathological gaming' is still a controversial one [4].

The literature has emphasized the importance of personality in IGD and that many personality characteristics are linked to it [5] & [6]. One of them being the Dark Tetrad traits that have grown in popularity in the last decades. Originally, it was composed of Machiavellianism, Psychopathy, Narcissism and later Sadism was added to it [7]. Together they measure the "dark" side of personality and are prevalent in many addictions such as substance abuse addictions [8] & [9].

Some debate that IGD is not a homogenous disorder [10], thereby distinguishing between different motivations for gaming can provide a better understanding of the disorder. Some gaming motivations have been known to be more problematic than others [11], and some motivations are more common in certain genres [12]. Several scales have been developed to measure motivations for gaming such as Nick Yee's motivations for online games [13], which mostly centered around MMORPG genre of games, and Motives for online gaming questionnaire or MOGQ that measures motivation more broadly across different genres of games [14] and has been evaluated in Iranian population [15].

One of the risk factors for IGD is emotional dysregulation [16] & [17]. However, according to the I-PACE model [18] while personality predispositions might initiate an addiction, emotional and cognitive factors help to maintain an addictive behavior in the later stages. Thus, emotional dysregulation might mediate the role of personality to IGD. While this has been studied for problematic social network usage [19] and similar circumstances, it has not been explored in the context of Internet Gaming.

There are no studies that have investigated the mediating role of emotional regulation between personality and IGD. Moreover, the relationship between IGD and Dark Tetrad traits has yielded contrasting results in the literature [20], [21] & [22] this relationship has not been investigated in the Iranian population.

1.2. Purpose of the study

This study aimed to investigate the relationship between Internet Gaming Disorder, Dark Tetrad traits of personality, motivations for online gaming and dysfunctions in emotion regulation in a sample of high school students.

2. METHODS AND MEASURES

2.1. Participants and procedure

Participants of this study were all the population of a boy's high school in an affluent neighborhood in Tehran (N=216) that filled out a pen and paper survey about internet gaming. Participants were informed about the goals of the study and the confidentiality and anonymity of their answers. We excluded those cases that did not play any games in the last 12 months, left any questionnaires empty, or showed extreme lack of variance in their responses. Thereby, 184 responses were considered valid. For those that left few questions unanswered we used linear interpolation method to fill out the missing data. Statistical analysis was used to interpret and analyze the data.

2.2. Measures

Gaming behavior

Demographic questions included age, relationship status, occupation status, and last studying degree. However, since all were full-time students only their age was considered in the analysis. In the survey there were questions about gaming behavior. specifically, the number of hours they spend playing online games per week (from less than 7 hours, to more than 42 hours per week), hours playing offline games per week (same frequencies), the devices they play games with (PC, Consoles, or phones) and frequency of their use ("never", "at least once a year", "at least once a month", "at least once a week", and "at least once a day"), genres of games they play (MOFPS, MMORPG, MOBA, Battle Royale, TBS, and others) and their frequency as well.

Persian translated version of Ten-Item Internet Gaming Disorder test (IGDT-10)

For measuring Internet Gaming Disorder, IGDT-10 questionnaire was used that is validated cross culturally [23], including in Iran, and consists of 10 items that measure the nine criteria of Internet Gaming Disorder (IGD) mentioned in the DSM-5 on a 3-point Likert scale ("never", "sometimes" and "often"). In scoring, all items that are marked as "often" are scored as one point except for items 9 and 10 that measure the same criterion and marking "often" in any or both counts as one point, thereby, valid scores range from 0-9 and 5 is the cut-off score for categorizing participants as risky "disordered" gamers. The scale was translated into Persian language and its validity and psychometric properties were evaluated in a sample of Iranian population by Rafiemanesh [24] which showed to possess good reliability.

Persian translated version of Motives for Online Gaming Questionnaire (MOGQ)

MOGQ is a 27-item questionnaire developed by Demetrovics [25] that measures an individual's motives of online gaming on a 5- point Likert scale ('never' to 'often'). The instrument consists of 7 domains: social, competition, coping, skill development, fantasy, escape, and recreation. MOGQ was translated into Persian language and its psychometric properties were evaluated in Iranian population by Hamzehzade [15] and has shown acceptable to good reliability.

Persian translated version of Short Dark Tetrad (SD4)

SD4 is a 28-items questionnaire developed by [7] that measures four dark personality traits (Machiavellianism, Psychopathy, Narcissism, and Sadism) on a 5-point Likert scale and all subscales are comprised of 7 items. This scale was translated into Persian language and its reliability and validity was evaluated in a sample of Iranian people by Bagajan, k. [26] and has shown acceptable to questionable reliability.

Brief Persian version of The Difficulties in Emotion Regulation Scale (DERS-16)

DERS-16 [27] is a brief version of DERS questionnaire [28] that is shortened to 16 questioned from 36 and measures emotion dysregulation on 5 subscales: lack of emotional clarity, inability to engage in goal-directed

behaviors, nonacceptance of negative emotions, difficulties controlling impulsive behaviors when distressed, and limited access to emotional strategies perceived as effective. The questions are presented on a 5-point Likert scale from 1 (almost never, 0-10% of times) to 5 (almost always, 90-100% of times). Total scores range from 16-80 and higher total scores mean higher difficulties in emotion regulation. Reliability reported for this scale was very good [27]. This scale was translated into Persian, and its psychometric properties was evaluated as well [29].

2.3. Data Analysis

Data were analyzed by SPSS software version 27. In the MOGQ scale, subscale scores were converted to mean so all domains with different number of questions could be weighed equally against each other. Same procedure was done to SD4 scale but not to DERS-16 scale scores. Moreover, as data were not normally distributed according to Shapiro-Wilk test, spearman correlation was used for nonparametric correlation analysis. Also, linear regression analysis was done with IGD as the dependent variable. P values less than 0.05 were deemed statistically significant.

3. RESULTS

3.1. IGD's characteristics

Of 184 valid respondents all were male and their age ranged from 14 to 18 with a mean of 16.58 years (SD=0.70). All were full time high school students. Descriptive statistics along with skewness, kurtosis and Cronbach's alpha for each studied variables are presented in the table 1. All scales showed acceptable to good reliability except for Machiavellianism which will be discussed in the discussions. Frequencies of respondent's playing time in week playing offline and online games are reported in the table 2.

Table 1. Descriptive statistics, and reliability of the variables

	Mean	Median	SD	Skewness	Kurtosis	Cronbach's alpha
IGD	1.37	1	1.50	1.10	0.58	0.64
Machiavellianism	3.384	3.42	1.03	-0.15	0.16	0.52
Narcissism	3.15	3.14	1.15	-0.15	-0.14	0.67
Psychopathy	2.46	2.42	1.14	0.27	-0.32	0.61
Sadism	2.92	3	0.79	-0.04	-0.41	0.71
SD4 total	11.93	12	1.75	-0.14	0.18	0.77
Social	2.48	2.25	1.03	0.50	-0.68	0.71
Escape	2.63	2.5	1.16	0.33	-0.98	0.86
Competition	3.07	3	1.14	-0.07	-1.03	0.84
Coping	2.76	2.75	0.95	-0.03	-0.90	0.69
Skill development	2.76	2.75	1.06	0.07	-0.99	0.80
Fantasy	2.48	2.37	1.18	0.39	-0.98	0.81
Recreation	4.21	4.33	0.84	-1.27	1.51	0.77
MOGQ total	20.42	20.5	4.77	0.01	-0.82	0.89
Clarity	3.78	3	1.76	0.93	0.17	0.64
Goals	7.86	8	3.01	0.41	-0.51	0.71
Impulse	6.66	6	3.11	0.81	-0.01	0.84
Strategies	10.78	10	4.40	0.74	-0.15	0.75
Non-acceptance	6.63	6	3.10	0.94	0.17	0.71
DERS total	35.73	34	11.62	0.63	-0.30	0.87

IGD= Internet Gaming Disorder, SD4: Short Dark Tetrad of personality, MOGQ: Motives for Online Gaming Questionnaire, DERS: Difficulties in Emotion Regulation Scale

Table 2. Frequencies of hours spent per week playing online and offline video games

hours	Online	Offline
	Frequency (percent)	Frequency (percent)
0	3 (1.6)	34 (18.5)
0-7	72 (39.1)	60 (32.6)
7-14	33 (17.9)	35 (19.0)
15-28	23 (12.5)	7 (3.8)
29-42	9 (4.9)	4 (2.2)
>42	4 (2.2)	3 (1.6)
missing	40 (21.7)	41 (22.3)
Total	184	184

The most common criteria of IGD are depicted in the table 3. The prevalence of each criterion was investigated in the total population, for each genre (MMORPG, MOBA and so forth), and for each device (PC, Consoles, and phones). Those reported playing a genre or a device for at least once a week or more were classified into each group.

Table 3. Frequencies of each IGD criterion in the total sample population, gaming genres, and devices. Frequency (percent).

	Total popula tion (184)	MMORP G (16)	MOB A (34)	MOFP S (67)	BATTL E ROYAL E (67)	MORT S (16)	PC (100)	CONSOL E (105)	PHON E (124)
without IGD criterion	69 (37.5)	3 (18)	10 (29.4)	17 (25.4)	21 (31.3)	5 (31.3)	37 (37)	37 (35.2)	42 (33.9)
1- Preoccupation	29 (15.8)	2 (12.5)	6 (17.6)	17 (25.4)	15 (22.4)	2 (12.5)	18 (18)	18 (17.1)	23 (18.5)
2- Withdrawal	14 (7.6)	0	2 (5.9)	6 (9)	6 (9)	2 (12.5)	4 (4)	8 (7.6)	10 (8.1)
3- Tolerance	39 (21.2)	3 (18.8)	4 (11.8)	17 (25.4)	15 (22.4)	3 (18.8)	15 (15)	26 (24.8)	27 (21.8)
4- Loss of control	19 (10.3)	0	3 (8.8)	8 (11.9)	9 (13.4)	3 (18.8)	8 (8)	11 (10.5)	14 (11.3)
5- Giving up other activities	20 (10.9)	5 (31.3)	6 (17.6)	8 (11.9)	8 (11.9)	2 (12.5)	13 (13)	10 (9.5)	11 (8.9)
6- Continuation	28 (15.2)	5 (31.3)	9 (26.5)	17 (25.4)	14 (20.9)	1 (6.3)	16 (16)	14 (13.3)	21 (16.9)
7-Deception	19 (10.3)	2 (12.5)	3 (8.8)	6 (9)	7 (10.4)	6 (37.5)	11 (11)	11 (10.5)	16 (12.9)
8- Escape	67 (36.4)	9 (56.3)	16 (47.1)	29 (43.3)	29 (43.3)	7 (43.3)	42 (42)	40 (38.1)	50 (40.3)
9- Negative consequences with IGD disorder	18 (9.8) 9 (4.9)	1 (6.3) 0	7 (20.6)	11 (16.4)	6 (9) 5 (7.5)	1 (6.3) 0	12 (12) 4 (4)	12 (11.4) 6 (4.8)	13 (10.5) 9 (7.2)

Note: MMORPG: massively multiplayer online role-playing games, MOBA: multiplayer online battle arena, MOFPS: multiplayer online first-person shooter, MORTS: multiplayer online real-time strategy, PC: personal computer.

‘Escape’ was the most common IGD criterion in the total population (36.4%) and across all genres of gaming and devices. The second most common criterion in the total sample population was ‘Tolerance’ (21.2%) but it was different

for genres and devices. Motives for gaming was compared in each genre and each device with the total population and no significant difference was found, however more data are required to reach a conclusion.

3.2. Relationships among variables

Heat map correlation matrix of the variables is available in figure 1. The lighter colors indicate higher correlations. According to the results, age and hours playing offline games did not correlate with IGD but number of hours playing online showed significantly positive correlation with IGD. IGD showed statistically significant correlation with 3 of the Dark Tetrad traits (Machiavellianism, Psychopathy, and Sadism). Also, IGD's correlations with MOGQ motives and DERS and its subscales were significant as well (except for nonacceptance of negative emotions). There were significant correlations between Dark Tetrad traits, motives and emotional dysregulation which suggests indirect paths from one variable to the next leading to IGD. For example, narcissism and psychopathy had significant positive relationship with competition motive which itself has significant relationship with IGD; However, Narcissism showed no direct significant correlation with IGD.

3.3. Predicting IGD

Using simple linear regression analysis, 6 models have been analyzed to predict IGD that are depicted in table 4. In the first model the predictor variables are number of hours playing online, online gaming motives, Dark Tetrad traits, and Emotional dysregulation subcategories. In the second model just the Dark Tetrad traits are used as the predictors, the third model emotional dysregulation subcategories, In the fourth model online gaming motives, in the fifth model both Dark Tetrad traits and emotional dysregulation subcategories, and in the sixth model the total scores of MOGQ, SD4, and DERS are used as the predictors. The estimates for bivariate and multivariate (first model) regression are depicted in the table5.

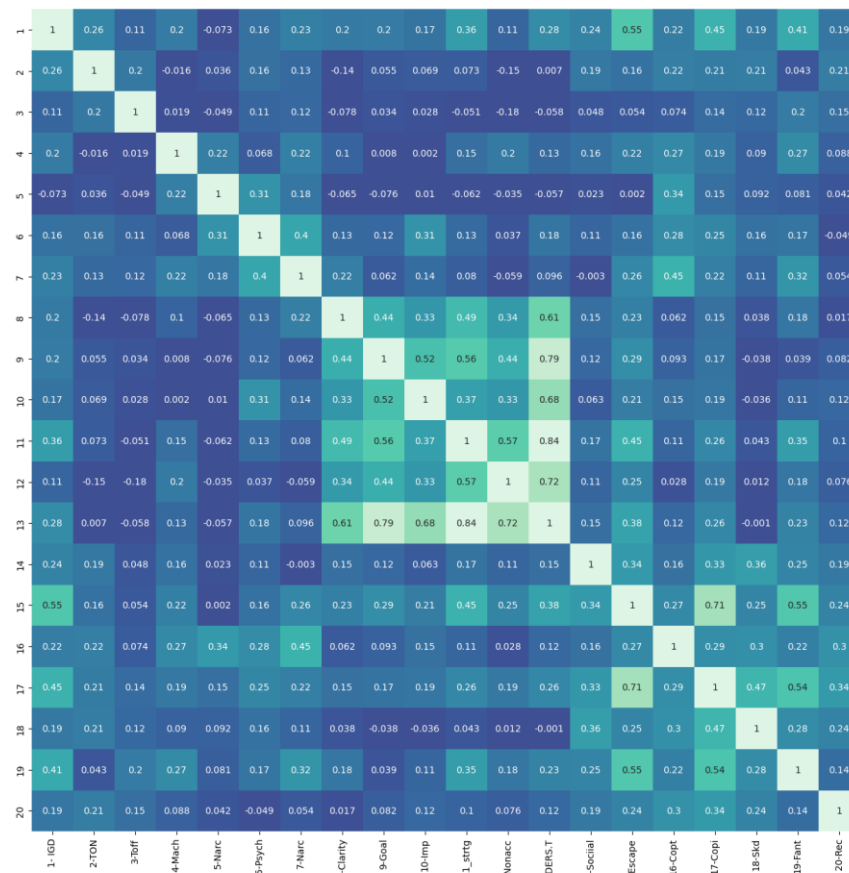


Figure 1. Heatmap correlation of the variables. The lighter colors show higher correlations. IGD= Internet Gaming Disorder, TON= time spent playing online, TOFF= time spent playing offline, Mach= Machiavellianism, Narc=

Narcissism, Psych= Psychopathy, Sad= Sadism, Imp= impulsivity, Strtg= Strategies, Nonacc= Non-acceptance, DERS.T= Dysfunctional Emotion regulation total score, Copt= Competition, Copi= Coping, Skd= Skill Development, Fant= Fantasy, Rec= Recreation

Table 4. Results of regression analysis of several models

Model	Predictors	F	df	P-value	R2	R2 adjusted
1	MOGQ, SD4, DERS subscales, hours online	5.40	17,126	<0.001	0.422	0.344
2	SD4	4.65	4,179	<0.001	0.094	0.074
3	DERS subscales	5.46	5,178	<0.001	0.133	0.109
4	MOGQ	12.63	7,176	<0.001	0.334	0.308
5	SD4 and DERS	4.54	9,174	<0.001	0.190	0.149
6	Total scores of MOGQ, SD4, and DERS	23.46	3,180	<0.001	0.281	0.269

MOGQ= Motive for Online Gaming, SD4; Short Dark Tetrad, DERS: dysfunctional emotion regulation

Table 5. Estimates coefficients of univariate and multivariate linear regression. Multivariate regression is the first model.

Predictors	Regression coefficients from univariate regressions				Regression coefficients from multivariate regression			
	B	Std. β	95% CI	P-value	B	Std. β	95% CI	P-value
hours online	0.34	0.24	0.11,0.57	0.004	0.17	0.11	-0.05, 0.39	0.131
social	0.42	0.29	0.22,0.62	<0.001	0.21	0.14	-0.02, 0.45	0.077
escape	0.70	0.54	0.54,0.86	<0.001	0.44	0.34	.013, 0.74	0.005
competition	0.30	0.22	0.11,0.48	0.002	0.04	0.03	-0.19, 0.29	0.699
coping	0.63	0.39	0.41,0.84	<0.001	0.04	0.02	-0.35, 0.44	0.830
skill development	0.25	0.17	0.04,0.45	0.016	0.01	0.01	-0.25, 0.27	0.942
fantasy	0.53	0.42	0.36,0.70	<0.001	0.12	0.10	-0.11, 0.37	0.296
recreation	0.29	0.16	0.04,0.55	0.024	0.04	0.02	-0.25, 0.34	0.764
machiavellianism	0.52	0.18	0.11,0.93	0.012	0.10	0.03	-0.31, 0.53	0.615
narcissism	-0.03	-0.01	-0.37,0.31	0.865	0-.09	-0.04	-0.46, 0.27	0.608
psychopathy	0.37	0.16	0.05,0.70	0.023	0-.05	-0.02	-0.44, 0.33	0.775
sadism	0.46	0.24	0.19,0.73	<0.001	0.23	0.12	-0.13, 0.61	0.211
clarity	0.22	0.26	0.10,0.34	<0.001	0.06	0.07	-0.08, 0.21	0.383
goals	0.11	0.22	0.3,0.18	0.003	0-.01	-0.02	-0.11, 0.08	0.767
impulse	0.05	0.11	-0.01,0.12	0.124	0-.01	-0.03	-0.10, 0.07	0.699
strategies	0.11	0.34	0.07,0.16	<0.001	0.04	0.11	-0.03, 0.11	0.282
non-acceptance	0.07	0.16	0.01,0.14	0.027	0-.02	-0.05	-0.11, 0.06	0.542
MOGQ total score	0.15	0.50	0.11,0.19	<0.001			-	
SD4 total score	0.19	0.22	0.07,0.31	<0.001			-	
DERS total score	0.03	0.30	0.02,0.05	<0.001			-	

Results of regression analysis showed that model 1 could explain 42% of the variance in IGD, but the only significant variable was escape motivation with a standardized β of 0.34. In the second model Dark Tetrad traits could account for 9.4% of the variance in IGD and in the univariate regression all traits except for narcissism were significant predictors of IGD. Overall, all models were significant.

4. Discussion

Characteristics of IGD

In our study prevalence of IGD was about 4.1% (9 out of 216). Prevalence of IGD has been reported from 10-4% in several studies with global samples [30] & [31] and a sample of Arab countries [32]. The diagnosis of IGD as a disorder is still a controversial one. We have used IGDT-10 as our screening tool, that is compatible with the categorical approach of DSM-5 diagnosis, however, others have used other screening tools for IGD, such as problematic online gaming [31]. The categorical vs dimensional approach to IGD debate is still ongoing, with some in favor of a hybrid model [33].

In the present sample all participants were male and full-time high school students. For that reason, we excluded the correlation of their relationship status and occupation status with IGD. The students came from a high socio-economic background and the school's environment is academically competitive and selective. This leaves little space for students to develop IGD. This is evident non-parametricity of IGD and lack of number of severe IGD cases.

We distinguished between time spent on online and offline games and found out only time spent playing online games was associated with IGD. However, surprisingly 55% (5 out of 9) of those who diagnosed as having IGD played for less than 1 hour a day. Which might mean that developing IGD is related to other problems as well as hours spent online.

All instruments showed appropriate reliability except for Machiavellianism trait with Cronbach's alpha of 0.518; however, this problem has been mentioned in other research as well. Rassin [34] reported alpha of 0.55 for Machiavellianism; Bagajan [26] reported alphas of 0.59. In a study conducted in a Muslim country [35] mentioned explicitly that certain questions in the SD4 scale are problematic, specifically question 6 "flattery is a good way to get people on your side"; which they removed for their reliability analysis. In our study this question yielded almost no item-total correlation (0.081) as well. We speculate that this construct does not generalize to middle eastern and Muslim cultures. Specifically, concerning question 6, the Persian translation of the word "flattery" does not convey the exact meaning and cultural sensitivities exist regarding the matter.

The most common criteria of gaming disorder in the total population were 'Escape' and 'Tolerance'. 'Escape' was also the most common criterion in each gaming genre and gaming device as well. According to Kiraly [23] 'Escape' was associated with lower IGD severity, while 'Tolerance' was associated with higher IGD severity.

'MOFPS' and 'Battle Royal' both were the riskiest genres with 7.5% of participants manifesting IGD and 'phone' was the riskiest device (7.2%). Means of motivations in different genres and devices did not significantly differ from each other, however, more data is needed for a clear discrimination.

Relationships

The highest correlation between IGD and any variable belonged to 'escape' motivation from MOGQ. This is not surprising since the most common IGD criteria was 'escape' as well. Both relate to 'escaping from reality and its problems'; however, one measures this in the context of motivation and the other in a clinical framework. After that, 'coping' had the highest correlation with IGD which might be due their shared origin with 'escape' as one factor [14].

IGD showed significant correlations with Machiavellianism, Psychopathy, and Sadism but not with narcissism. Researchers have produced contrasting results, some with similar results to ours [20], and some contrary [21]. Dark Tetrad significantly predicted IGD explaining 9.4% of its variance.

In general difficulties in emotion regulation domains had significant correlations with IGD and they could predict IGD significantly, explaining 13.3% of the variance.

Intercorrelations

There were some correlations between Dark Tetrad traits and gaming motivation. For example, 'competition' motive was correlated with all Dark traits, Same with 'coping'. 'Escape' was correlated mostly with Machiavellianism and sadism. Interestingly, 'skill development' was correlated with psychopathy which needs to be further evaluated. This finding is compatible with other studies mentioning Dark Tetrad traits are associated with high competitiveness [36] & [21].

There exists some correlation between Difficulties in Emotion Regulation and motivations for online gaming. Notable ones are the correlation of 'escape' with all domains of DERS and correlation of 'coping' and 'fantasy' with many domains.

Emotional Dysregulation total score was only associated with psychopathy, and this was only due to the correlation of psychopathy with impulsivity which is congruent with pioneering studies [37]. Other weak correlations between DERS domains and dark tetrad existed too.

These inter correlations between these constructs point to existence of indirect paths to IGD that need to be investigated in future works.

Practical Implications

Assessing gaming motivations could be insightful for practitioners for understanding IGD, since it is not a homogenous disorder [10] and may require different treatments tailored for different people [33]. For example, one study [38] mentioned that gaming motivations could be used to recommend target behaviors for behavior replacement therapy. As Dark Tetrad are present in addictions especially internet and substance abuse [21], and could make treatments complicated, their study could be useful to clinicians. For example, the presence of psychopathy and impulsivity should suggest treatments that address treating impulsive behaviors as well as pathological gaming.

limitations

limitations of this study are low number of samples, their limited age range, and its generalizability to the total population. Self-administered surveys are prone to bias and unreliability. Although all the participants in the study were male, this is congruent with the nature of IGD as mostly male are affected. The current sample consisted of a low number of severe IGD cases which makes analyzing the relationships less meticulous; future studies benefit by addressing this sampling problem. Other confounding variables such as occupation status, relationship status, and socio-economic status should be included in the future studies as well. Participants gaming time are self-reported and maybe biased and unobjective. Future research should investigate the indirect mediation effects of the variables as well as direct effects. Possible moderating variable should be investigated as well.

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Synthesis of melamine formaldehyde nanocomposite with surface modified silica nanoparticles for chemical consolidation of sandstone reservoirs

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ABSTRACT

Production of sand in sandstone reservoirs is considered a fundamental issue in some oil and gas fields due to the damages and economic problems it brings. Sand production leads to the occurrence of numerous problems, including erosion of oil exploitation equipment, environmental damage, reduction and interruption in production, and sometimes loss of the well. Therefore, it is very important to control sand production from sand producing wells. So far, various methods, including mechanical and chemical, have been presented and carried out to control sand production, and in chemical methods, the sand formation is consolidated through the injection of polymer fluid, such as various resins, polymer gels, etc. In the background of the research, action and tests carried out in the use of different types of resins to consolidate sandstone reservoirs, the obtained results have shown the success of resin injection. In this study, modified nano silica surface was used for chemical consolidation along with melamine formaldehyde aqueous base resin synthesized in the laboratory. The results of Fourier Transform Infrared Spectroscopy (FTIR), Thermogravimetric Test (TGA), compressive strength and permeability tests show the success of surface modification of silica nanoparticles and the efficiency of the synthesized nanocomposite as a chemical consolidation fluid.

Keywords: Chemical consolidation, surface modification, nanocomposite, sandstone reservoirs

1.INTRODUCTION

Sand production is one of the biggest problems faced by the oil industry. Hundreds of oil and gas fields around the world are affected by this problem, and millions of dollars are spent every year on predicting sand production, controlling sand, and repairing wells and well equipment. Formation sand production is the result of unconsolidated or detached sand grains around the well [1]. The instability of the reservoir causes that when the fluid passes through the porous medium, the sand particles are separated from the reservoir rock and move along with the fluid, and as a result, this phenomenon leads to the production of sand along with the production fluid. The production of sand along with fluid can cause wear in the brain tube, wear in the well head facilities and also block the production fluid flow [2, 3]. Many researchers have used polymers to consolidate sand, because this type of material does not have much viscosity and provides enough compressive strength to consolidate sand. Using these types of materials, the polymerization time can be controlled, they are relatively inexpensive, and some of them can be used at high temperatures. Aqueous-based polymers and microgels tend to adsorb on the rock surface, hence creating a protective layer to control erosion [4]. Resin injection as a sand control method has been in the industry since the early 1940s [5]. Some examples of organic resins that can be suitably used for chemical consolidation are polyester resins, phenol-formaldehyde resins, epoxy resins, furan resins, urea-formaldehyde resins, urethane resins, melamine-formaldehyde resins, and combinations of these types of resins [6]. Melamine formaldehyde (MF) is one of the hardest polymers of the thermostat. MF is a type of amino resin that shows intrinsic fire resistance due to its high nitrogen content [7]. Melamine formaldehyde has various material advantages such as good hardness, thermal stability, scratch resistance, wear resistance, flame resistance, moisture resistance, which leads MF to large industrial applications [8]. The

presence of three amine groups in melamine allows more bonds to be established [9]. In order to improve the physical and mechanical properties of water-based coatings, several methods have been suggested, among which the use of different nanoparticles has received more attention [10]. Although silica can improve properties such as hardness, modulus, abrasion resistance, thermal stability and rheology of composites, it cannot be easily used in polymer or organic systems, the reason being the large difference in the properties of polymer and reinforcing particles, which can lead to phase separation [11-15]. The proper properties of nanocomposites are obtained when nanoparticles are uniformly distributed in the polymer substrate [16]. By improving the distribution of nanoparticles on the polymer surface, a better interface between the nanoparticles and the polymer substrate is created [17]. In general, modification of the surface of silica nanoparticles can usually be done by physical and chemical methods. In recent years, chemical modification has received much attention due to the strong interactions between the modifier and the surface. Chemical modification of silica surface is done by using modifying agents and grafting to polymers. Different modifying compounds of silicon, titanium, boron, aluminum, etc. are used, but usually silane absorbing agents are used [18, 19]. The selection of the type of silane absorbing agents is based on the type and structure of the polymer network and the type of existing interactions [20]. In the surface modification reaction, silanol obtained from the hydrolysis of silane first approaches the hydroxyls of the silica surface through hydrogen bonding, and as the reaction continues and water is removed, a covalent bond is established between silica and silane [21]. Adding silica nanoparticles (SiO_2) to urea formaldehyde improved the mechanical properties of urea formaldehyde and also increased its resistance to water [22]. Krysztalkiewicz et al. modified the surface of nano-silica to obtain hydrophobic silica whose properties allow it to be used as a plasto- and elastomeric filler. They modified the silica surface using silane and titanate coupling agents. Changing the surface of silica by coupling agent's silane and titanate significantly changed the morphology and aggregation of particles, in the microscope images, clearly reduced the size of grains and aggregation of particles in the presence of silane modification agent [23]. The effect of nano silica surface modification with 3-aminopropyltriethoxysilane (APTES) on the kinetics and thermal stability of urea formaldehyde (UF) resin was investigated. Silica modification led to an increase in the thermal stability of UF resin [24].

EXPERIMENT

2.1 Material

Melamine was supplied by Urmia petrochemical company (Iran). Formalin provided by Nakhil Asmari Petrochemical Company (Iran). Sodium hydroxide and toluene were obtained from Bandar Imam Petrochemical Company (Iran). Methanol was supplied by Fanavaran Petrochemical Company (Iran). Ethanol SHimibaft obtained from Petrochemical Company (Iran). 3-aminopropyltriethoxysilane was purchased from Merck Group (Germany). Nanosilica purchased from Jiangsu Xfnano (China).

2.2 Preparation

For the synthesis of melamine-formaldehyde resin, in a three-hole balloon in a hot water bath at 85°C , 0.3 mol of formaldehyde is combined with 0.1 mol of melamine and the pH is adjusted between 8.5 and 9.5 with 33% sodium hydroxide. After some time from the start of the reaction, methanol was added to it and the pH was raised to 6 with oxalic acid, after 15 minutes the pH was raised to 8.5 with sodium hydroxide and the reaction continued for one hour.

To modify the surface of silica nanoparticles using 3-aminopropyltriethoxysilane (APTES), firstly, to calcine nano-silica, the nanoparticles are placed in a vacuum oven for two hours at a temperature of 200°C . 8.8 ml of APTES, 8.8 ml of deionized water and 35 ml of ethanol are combined and stirred for one hour using a magnetic stirrer until a clear solution is obtained. 8 g of nano-silica with 160 ml of toluene are poured into a three-necked flask at a temperature of 80°C and stirred for 30 minutes. Slowly add the hydrolyzed APTES to the above mixture over 45 minutes and after adding all the APTES, stirring is continued for 4 hours. to obtain a mixture with a pale-yellow color. Figure 1 shows the process of modifying the surface of silica nanoparticles. Then it is put in ultrasonic for 2 hours. Then it is washed

five times with ethanol by centrifugation at 6000 rpm. It is placed in a vacuum oven for 24 hours at a temperature of 110°C to dry. Figure 2 shows the modified nano silica sample after drying.



Fig. 1. The surface modification process of silica nanoparticle

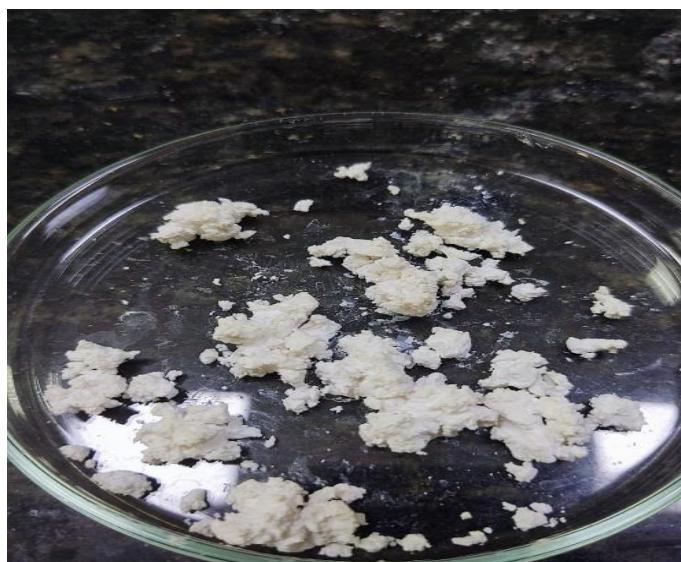


Fig. 2. Modified nano silica sample

The synthesized melamine-formaldehyde resin is poured into a three-hole balloon and modified nano-silica is added to it. Stirring continues for one hour at 75°C. Then it is placed in an ultrasonic bath for 1 hour.

MEASUREMENTS

3.1 Fourier transform infrared (FTIR) Spectrometer

Figure 3 shows the results of FTIR for modified and unmodified silica nanoparticles. As can be seen in the FTIR spectrum of unmodified nano-silica, the peaks in the range of 1100 cm^{-1} and 1630 cm^{-1} wave numbers, respectively, are caused by Si-O-Si and O-H groups, as well as the peak in the range 3300 cm^{-1} to 3600 cm^{-1} is due to Si-OH group. The stretching vibrations of Si-O occur in the range of 802 cm^{-1} and the peak appearing at 470 cm^{-1} is due to the bending vibrations of Si-O. In the FTIR spectrum of modified nanosilica, the peak shown in the range of 3000-2800 cm^{-1} is caused by methylene groups, which also confirms the surface modification of silica nanoparticles with APTES agent.

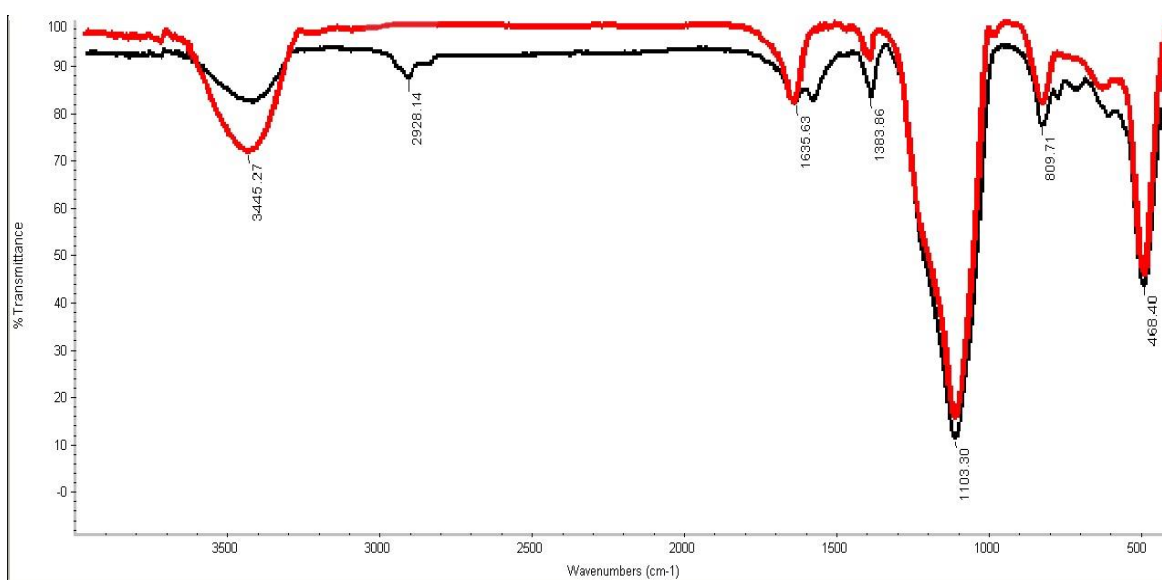


Fig. 3. FTIR test results for unmodified (red), modified (black) silica nanoparticles

3.2 Thermal gravimetric analysis (TGA)

The thermogravimetric test (TGA) was performed at room temperature up to 500°C with a heating rate of 10°Cmin⁻¹ under nitrogen gas. The results of the TGA test on the modified and unmodified nanocomposite are shown in Figure 4. Nano-sized fillers have a large surface area that makes them easily absorb moisture in a typical laboratory environment even after drying at 110°C for 6 hours. Considering that after modifying the surface of silica nanoparticles

with silane, the hydrophilicity of the surface has changed, modified nanosilica has absorbed less water at temperatures lower than 200°C. The weight loss of modified silica nanoparticles at temperatures below 200°C is related to the presence of water or unreacted APTES agent on the surface of silica nanoparticles. Also, the weight loss in the range of 300-500°C is related to the decomposition of organic groups and the breaking of the Si-OH bond. The second stage of thermal decomposition (from 200°C onwards) is caused by the decomposition of APTES agent, which is chemically linked to silica nanoparticles. The lower weight loss of modified nano-silica before 200°C shows that the surface modification was effective to prevent water absorption on the surface of silica nanoparticles. The temperature related to 5% weight loss and the maximum thermal decomposition temperature of the modified nanocomposite compared to the unmodified nanocomposite indicate the improvement of the thermal resistance of the nanocomposite.

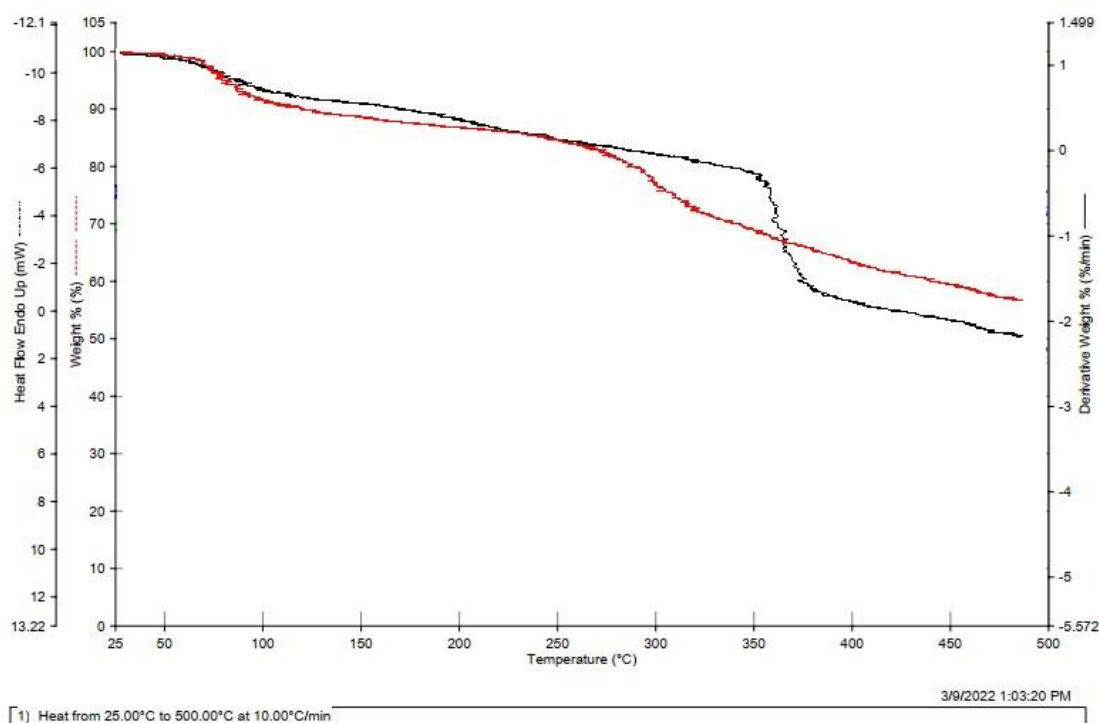


Fig. 4. TGA test results for unmodified (red) and modified (black) nanocomposite

3.3 Field emission scanning electron microscopy (FESEM)

FESEM analysis of core sample consolidated with nanocomposite shows that after consolidation of sand grains with this nanocomposite, a much larger part of empty spaces and bottlenecks were available. Figure 5 shows an image of the FESEM analysis of the core sample consolidated with nanocomposite, in which you can see the sand particles sticking to each other. Also, in Figure 6, which shows a more open image with less magnification, you can see the existing empty spaces and bottlenecks. This shows that the nanocomposite based on melamine-formaldehyde resin occupies less space.

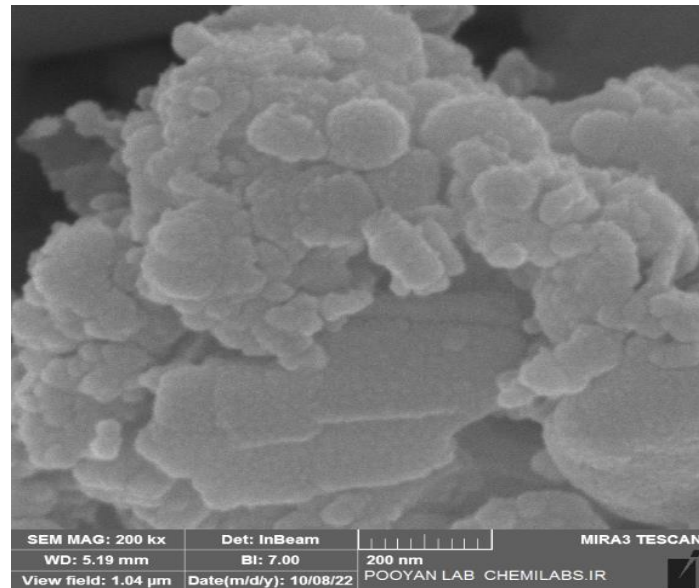


Fig. 5. FESEM analysis related to core sample consolidated with nanocomposite with 200 nm magnification

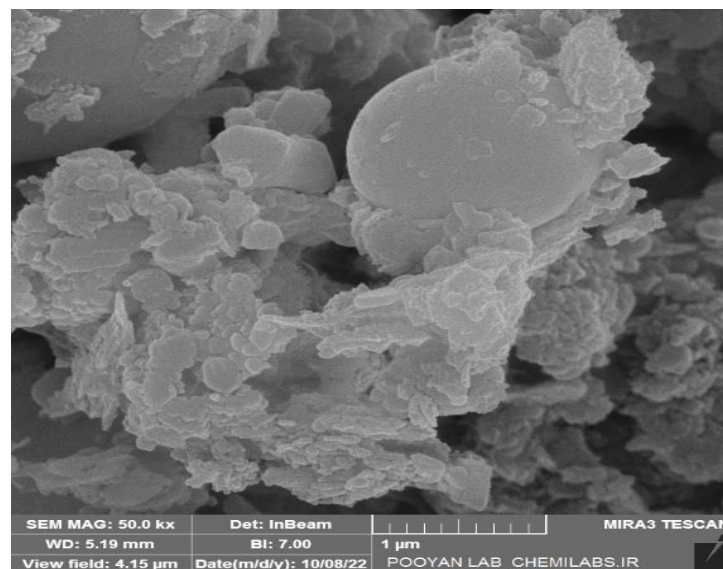


Fig. 6. FESEM analysis related to core sample reinforced with nanocomposite with 1 μm magnification

3.4 Porosity, permeability and uniaxial compressive strength

Formation damage device FDS-350, this device is designed and built basically with the purpose of evaluating the way and amount of penetration of fluids from mud or drilling cement, fluids entering the formation due to cleaning operations or chemical injection into wells. Figure 7 shows a view of this device. The evaluations are based on the

measurement of the absolute permeability of the samples to different fluids and their comparison at different time stages (for example, before and after the injection of each specific fluid). The sample of plug consolidated with melamine formaldehyde resin and melamine formaldehyde resin with modified nano silica is shown in Figure 8.

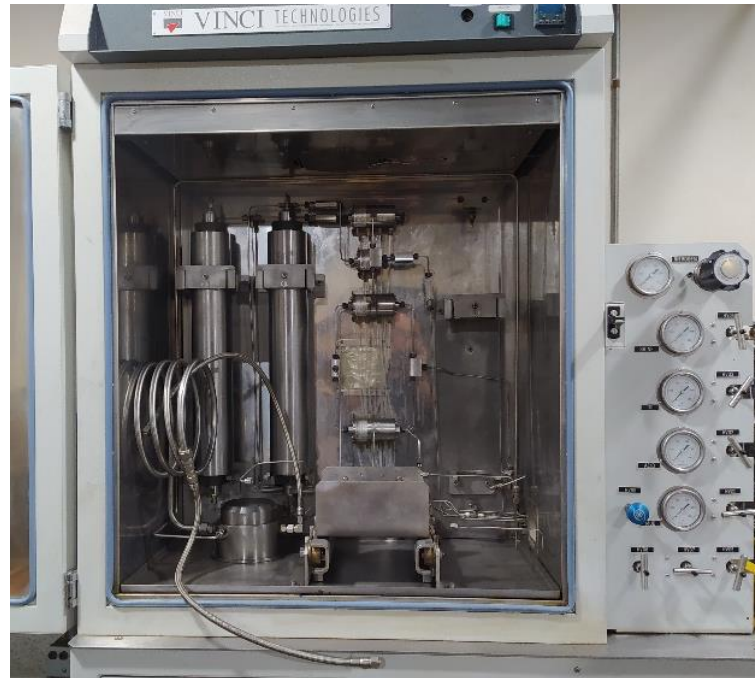


Fig. 7. Formation damage device FDS350 in formation damage laboratory



Fig. 8. Plug consolidated with melamine-formaldehyde resin (a) and melamine-formaldehyde resin with modified nano-silica (b)

Table 1 shows the effect of nanocomposite injection based on melamine formaldehyde resin on porosity, permeability and uniaxial compressive strength. This nanocomposite has been able to increase the uniaxial compressive strength between 112 and 362 psi, but the permeability has decreased between 25 and 41%.

Table 1. The effect of nanocomposite injection on porosity, permeability and uniaxial compressive strength

CORE	Hardener (%)	Increased compressive strength (psi)	Primary porosity (%)	Secondary porosity (%)	Primary permeability (md)	Secondary permeability (md)	Residual permeability (%)
A-1	2	112	33.60	17.49	120.22	90.16	75
A-2	5	251	34.26	18.42	232.59	158.16	68
A-3	7	362	34.87	18.43	325.38	191.97	59

In Figure 9, changes in the increased compressive strength and the residual permeability in different percentages of hardener can be seen.

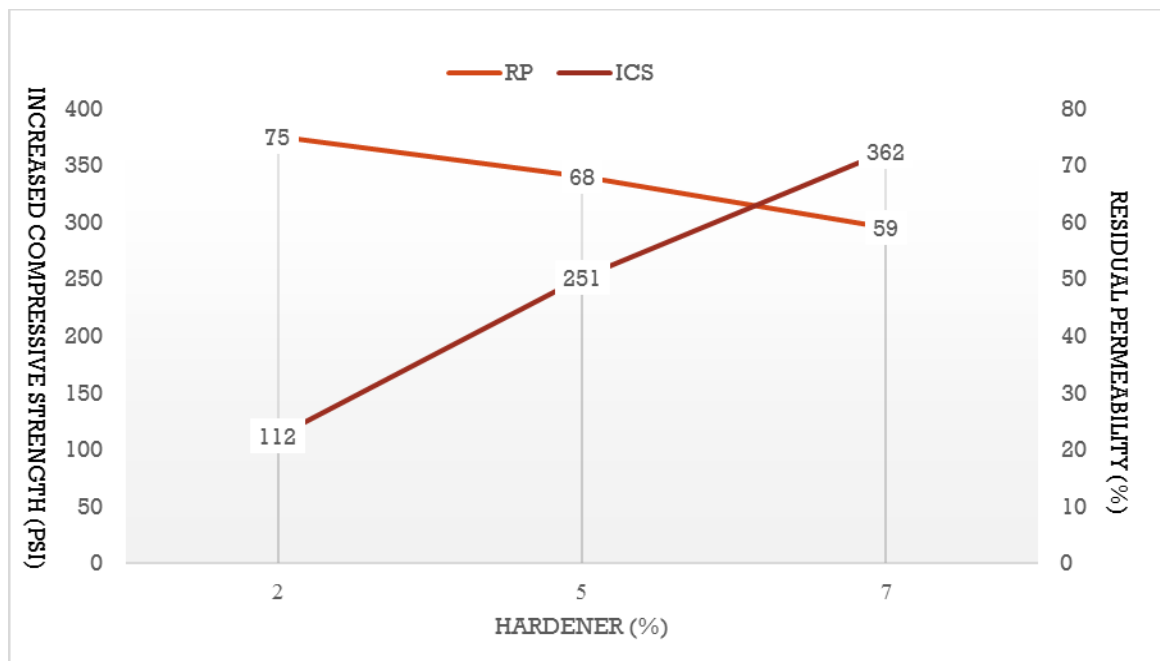


Fig. 9. Increased compressive strength (ICS) and the residual permeability (RP) in different percentages of hardener

3.5 Viscosity

The result of the viscosity shows the low viscosity of the modified nanocomposite, which is suitable for pumping, injecting into the formation and penetrating deep into the reservoir. The result of viscosity is shown in Table 2.

Table 2. viscosity of the modified nanocomposite

Viscosity (cP)	Temperature (°C)	Torque (%)	Speed (rpm)
49	25	4.9	40

CONCLUSION

The results of the FTIR test indicated the successful chemical modification of the surface of silica nanoparticles by the silane agent. The TGA test showed an increase in thermal resistance for the modified nanocomposite compared to the unmodified nanocomposite. The results of increased compressive strength and preserved permeability showed that water-based resins can also create strength in sand particles like solvent-based resins. The consolidated plugs showed that increasing the amount of hardener by 7% reduced the permeability by 59% and increased the compressive strength to 362 psi. Due to the low viscosity of nanocomposite, it is an ideal option for injection into sandstone reservoirs.

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Study of training factor for personnel in order to reduction of the H₂S gas leakage in Oil & Gas drilling rigs

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Abstract

Drilling rigs are one of the main components in the oil and gas industry. Various operations in the rigs are faced with many dangers and risks. These risks include technical, environmental, safety and economic dimensions, which can have serious effects on human health and the environment. In this article, the dangers and risks of H₂S gas leakage in oil and gas drilling rigs are discussed from a technical, safety and environmental point of view, which include risks caused by high pressure, H₂S gas leakage, environmental pollution, water effects and air, life injuries and non-life injuries for the personnel working in the rigs, and also includes issues related to the maintenance and monitoring of the rigs. Also, preventive, reduction and control measures to deal with these risks and optimal management of risks in the field of oil and gas drilling rigs are examined. These reviews can help improve safety performance and create effective standards, update risk assessment in drilling rig operations. The results of the research showed that the risks include explosion and fire, disturbances in the drilling process, life and non-life injuries for the personnel working in the rig and environmental pollution.

Keywords: education, dangers of H₂S gas (Hydrogen sulfide) and drilling rigs.

Introduction

One of the most important risks of geological and environmental engineering in drilling tunnels and oil and gas wells is encountering some natural gases such as hydrogen sulfide (H₂S) during drilling. Solving the risks and challenges related to the entry of this gas into tunnels and wells is very difficult and expensive. One of the important tasks in this situation is to predict and estimate the risk of H₂S gas in underground spaces and determine the appropriate method to deal with its engineering, safety and environmental problems. Hydrogen sulfide (also known as H₂S, sewer gas, swamp gas, stinky moisture, and sour moisture) is a colorless gas that is recognizable at low concentrations by its pungent "rotten egg" odor. It is highly flammable and highly flammable. It is poisonous [1]. Hydrogen sulfide gas or H₂S naturally exists in the earth in crude oil, natural gas reservoirs, volcanic gases and hot springs [2]. Hydrogen sulfide at concentrations as low as 0.01 to 0.03 ppm (Part Per Million) has a rotten egg odor, which is an excellent warning sign. However, at higher and more dangerous concentrations (about 100 ppm), it affects the nervous system and causes paralysis of the olfactory system, so personnel exposed to the gas may mistakenly think that there is no gas, or it was a transient wave of gas [3]. Due to the very high sensitivities regarding the dangers of H₂S gas, the OSHA (Occupational Safety and Health Administration) organization has many and comprehensive rules regarding various activities in places where there is a possibility of H₂S gas leakage (General Industry 29 CFR 1910, Maritime 29 CFR 1915, 1917, 1918, Construction 29 CFR 1926). One of the main components in the safety management mechanism is the evaluation of their safety performance. This important component is of special importance during the implementation of the project [4]. Because it causes the continuous improvement of the safety performance of the contractors and this improvement has a considerable effect on the status of the organization and the employer's projects. The result of this effectiveness is the reduction of accidents and diseases caused by work [5]. The word HSE is the Latin abbreviation of "health, safety and environment". This category is one of the most important issues that every person at any level in the work and life environment should pay attention to, and neglecting it sometimes causes

irreparable injuries and losses. will be. One of the problems of this system is that it is not possible after an audit based on the HSE-MS model (meaning the safety, health and environment management system. This system is designed to manage and control the safety, health and environment risks in an organization has been developed) commented on the compliance of an organization's HSE performance with this system, in practice auditors are forced to approve or disapprove the HSE performance of an organization based on the requirements of the HSE-MS model through their observations and findings. And it is not possible to determine an intermediate. Therefore, it is very important to evaluate the performance of the organization, and this requires the formulation of appropriate indicators [6]. In the well drilling and tunneling industries, a significant potential for health hazards inherent in the operation has been identified. Industrial companies have established many requirements for better management of these risks, which often go beyond legal obligations. Health performance indicators in the industry are a necessary part of an effective health management that promotes and improves the organization's health performance. In many countries, for the purpose of regular reporting, requirements have been established for the use and evaluation of health performance indicators, which meet the consistent standards of health management for the operations of a company at the global level. This issue facilitates the development of a performance standard among drilling companies with the aim of identifying and sharing the best possible practices [7]. In the drilling industry, the problem that exists is that operational works are not fully performed based on full compliance with drilling work standards and safety, health and environment (HSE) regulations, and more attention is paid to holding specialized and general training courses in line with Cultivation and work health is an essential issue. It is necessary to observe safety in order to protect and maintain the human force and equipment, for the personnel of the employer and for the contractors. Due to the fact that drilling operations are associated with the possibility of encountering high-pressure oil and gas layers, therefore, observing safety issues in this operation is of particular importance. Safety departments oversee the drilling operations based on HSE laws and supervise all related issues by compiling safety, health and environment plans (HSE Plan) [8]. Currently, working in the drilling industry is one of the most dangerous jobs in the world due to the many accidents that occur in it [9]. According to the contents that have been stated, the purpose of the present research is to investigate the training related to the dangers of H₂S gas leakage in drilling rigs. H₂S gas leakage is one of the basic hazards in drilling rigs, which has serious effects on workers' health and public safety. Training on recognizing, preventing, and improving performance when exposed to this gas is critical. This article examines the importance of education regarding the dangers of H₂S gas leakage in drilling rigs. This review deals with the educational content including knowledge of H₂S gas, measurement and detection methods, strategies to prevent contact with this gas, and operational methods in case of related incidents. Also, the evaluation of the effectiveness of various trainings and the promotion of training approaches to improve the ability of workers in facing these hazards are discussed and investigated as a basic component in the safety and training programs of the drilling industry. These studies can help to improve the safety performance in drilling rigs and reduce the risks caused by H₂S gas on the health and safety of workers.

Research background

[10] The accident is one of the important factors in the destruction of potentials in industries. Undoubtedly, the first step in controlling incidents is to analyze them in order to identify the root causes. Finding the root cause of the accident in order to improve the safety system and prevent the repetition of similar accidents is one of the principles of safety, health and environment management programs. Tripod-beta method is one of the incident rooting methods, which is widely used in the oil industry due to its special attitude towards the element of human error. In this research, using the aforementioned risk assessment method, the causes of the fire accident at Naftshahr Well No. 24 (June 2018) have been analyzed and investigated, and it was concluded during the investigations that training personnel to familiarize With environmental hazards, it is one of the most important control measures to prevent the mentioned accident. [11] in an article on the subject of individual training and cooperative behavior of employees, they concluded that employers who constantly seek to improve employee performance by investing in employee training, if employees wish, by holding various trainings can cause Promote collaborative behavior among their employees. [12] in their research entitled HSE (Health Safety Environment) risk assessment and management in land drilling rigs using the William & Fine Method showed that environmental aspects and health and safety risks, most of these consequences

are caused by the discharge of wastewater Unrefined to the environment, excessive heat and cold of the working environment of operational personnel, unusual noise and above the standard level of engines and machines of drilling machines, shift work (night work), waste disposal (disposal and burial of waste and garbage), work in height, carrying and handling heavy and extra heavy cargo and equipment, working next to pressurized lines, working in loud and abnormal areas, exposure to chemical substances, gas leaks, and body parts getting stuck between or inside the equipment. be According to the results of the risk assessment, it can be concluded that most of the possible consequences of their activities and risks are caused by the carelessness of personnel and lack of continuous monitoring, and the role of training in this can be more cooperation and more monitoring of equipment and operations. Leads. [13] In a research entitled comprehensive evaluation of environmental performance based on oil drilling in the sea, they concluded that with the development of drilling to produce more oil in the sea, the pollution of the marine environment is also increasing, which requires us to deepen the protection of resources. Marine and environment, oil drilling companies are important producers of environmental pollution. One of the most destructive environmental pollutants are substances impregnated with sulfur. This paper develops a comprehensive evaluation system of the environmental performance of offshore oil drilling. Finally, some suggestions are made, with the protection of the marine environment, the monitoring mechanism of the marine environment can be improved, which forms a suitable space for the protection of the marine environment. By advancing and providing necessary training for monitoring mechanisms, we can prevent more environmental pollution. [14] in a research titled using the structural equation model (SEM) to evaluate the effectiveness of the quality management system (QMS) ISO9001 on the performance of oil and gas drilling companies, they showed that in the oil and gas industry, the effectiveness of the relevant ISO, if the approach based on The process changes to a risk-based approach, i.e. leadership and commitment, competency framework, risk-based thinking, continuous improvement, focus on customer satisfaction and prevention of non-conformance. The role of employee training as a parallel factor can increase the relevant effectiveness. [15] In an article titled Innovations in Predicting Hydrogen Sulfide (H₂S) Gas Concentration, first provides the reader with basic information, hydrogen sulfide (H₂S) creates a hazardous environment during drilling. Real-time measurement of H₂S concentrations during drilling provides early indications, allows operators to take necessary precautions at the rig site, and ensures proper execution of rig operations. Several attempts have been made in the oil and gas industry to estimate hydrogen sulfide, but there is no proven method to accurately measure H₂S gas concentrations in real time during drilling. Mud logging (also known as surface data logging) can be used to predict H₂S concentrations during drilling. Although mud logging does not actually measure H₂S gas directly, some actual measurements can be used as proxies to predict H₂S gas concentrations. Then, several AML (Advance Mud Logs) inputs were selected to build the prediction model: methane, total normalized gas, calcite volume, dolomite volume and CO₂ (carbon dioxide). The result was that: Finally, the model showed that there is a very strong correlation between AML outputs and H₂S concentration with normalized total gas, which shows the highest correlation, followed by C1 gas (methane). Interpretation of potential H₂S gas at the site can lead to necessary precautions being taken at the rig site. Using an advanced mud logging service can not only identify areas where H₂S gas is present, but also act as an early warning system for potential drilling hazards. [16] in a study entitled H₂S monitoring technique for high-risk (oil and gas) wells stated that, during oil and gas exploration, harmful gases such as hydrogen sulfide often exist in the wells, which lead to risks such as the death of living organisms. And it explodes. In wells containing H₂S gas, this gas can leak out of the well in different ways with different concentrations, and the most practical methods are to prevent damages, rational monitoring and emergency measures. With the aim of the safety of the well site during the exploration and exploitation of reservoirs with high pressure, high temperature and high volume of H₂S gas, studies were carried out in three stages: the first stage of sources, i.e. places where there was a greater possibility of H₂S gas leakage (formations and Geological layers containing H₂S gas) are summarized based on field stages including well testing operations, work-over wells operations and production. Then the concept of warning weight for H₂S gas concentration is proposed and weight values corresponding to different warning levels are proposed. In the second step, H₂S gas leakage is modeled by advanced modeling software, and in this modeling, the equipment available at the well site, wind leakage rate and gas intensity are also used. In the third step, the location and number of monitors are recommended according to the operation routine, and emergency measures are suggested in response to industry standards and field experience. As a result, it was shown that the degree of danger of the leaked H₂S gas is different

with the work stage and location of the leak. The pattern of dispersion and concentration of H₂S gas is greatly influenced by wind and large rig equipment. Therefore, the signals received by the sensors must be analyzed to determine the actual data. By weighting the alarm signals, the accuracy and speed of the alarm can be improved and the false alarm can be effectively eliminated. Computer simulation shows that by using layered sensor distribution and warning system grading, the locations where H₂S gas leakage is most likely, the concentration change and gas leak detection can be effectively achieved. Therefore, countermeasures can be quickly chosen to create more safety. [17]

In an article entitled, Hydrogen Sulfide (H₂S) Gas Safety System for Oil Drilling Sites Using Wireless Sensor Network, toxic and combustible gases are one of the most notorious killers of oil and gas industry workers. For this reason, government systems and legislators have required the use of gas sensors in places where there is a possibility of these gases leaking. Until recently, wired gas sensor systems were used. Although they are difficult to install and may look unpleasant due to the presence of many wires around them, they are reliable, and they are also expensive to install and maintain. In contrast, wireless gas leak detection systems are flexible, easy to install and maintain. Also, in terms of energy consumption, these sensor models are different. According to the survey, wireless sensor systems are more efficient in energy consumption.

Research Methodology

In terms of results, this research is an applied research and from the variable point of view, it includes qualitative variables and is classified as a descriptive research and it is a survey. The spatial and thematic scope of this risk assessment of occupational accidents is in the drilling operations of oil and gas wells. In order to reveal the risk centers and assess the risks of the relevant processes and units in order to provide a framework and a systematic method for risk management. The time domain studied in this research was carried out in the period of 9 months and in the technical department of oil and gas drilling rigs. According to the topic of the research, the statistical population of this research is made up of experts and experts in HSE departments and companies providing services for dealing with toxic gases in oil and gas well drilling rigs, and also considering that the mentioned method It is expert-oriented and it is based on the opinions of experts, there is no need for sampling

findings

Drilling rigs are used as an essential part of the drilling process in the oil and gas industry. But the dangers associated with gases in drilling rigs can be serious. Some of the main risks are shown in the table on the next page:

Risks	Description	solutions	Actions
Explosion and fire	The leakage of flammable gases such as methane, carbon dioxide, sulfur dioxide and hydrogen sulfide in oil and gas wells can lead to explosions and fires. This can be caused by high gas density in an enclosed space, sudden ignition as a result of connections or high density, or ignition by thermal radiation	Using safety equipment such as gas leak and fire extinguishing notification systems, gas evacuation systems, notification and warning systems, regular training for all personnel, updating risk assessment and practical measures to implement HSE-MS & ISO 9001 systems	Use of safety equipment and notification of leaks from certain areas and Regular monitoring by using auxiliary services to deal with H ₂ S gas in the rigs Training and awareness of personnel about the nature of toxic gases and countermeasures
Disturbances in the drilling process	Gases such as hydrogen sulfide, which are colorless, toxic, and	Using safety equipment such as fire extinguishing systems,	The use of new technologies, the use of

	flammable, and tank gases (from methane to butane), which are odorless and flammable, can suddenly leak from oil and gas wells, and in some cases, they can cause respiratory failure and even death. death of personnel, explosion, fire of various parts of the .rig	gas evacuation systems, information and warning systems, and conducting various logs to identify gas-prone locations, regular training for employees, and updating risk assessment and practical measures for implementation. HSE-MS & ISO 9001 systems	ancillary services to deal ,with sour gas in the rigs Emergency planning Proper ventilation Review and update procedures and equipment with routine maintenance
Life and non-life injuries	The release of harmful gases, such as hydrogen sulfide, methane and sulfur dioxide, can lead to damage to the respiratory system of personnel at high levels .and even death	Risk Assessment Education and awareness Use of safety equipment Perform regular maneuvers Refer to guidelines and standards	Using ancillary services to deal with sour gas in the rigs and using safety accessories such as breathing capsules and air transfer systems to all areas of the rig

Risks	Description	solutions	Actions
Air and environmental pollution	In the environment, it can lead to air pollution, acid rain and negative .environmental effects	Non-contamination of various substances with sulfur-containing substances, establishment of facilities for separating sulfur from other pollutants, holding training courses for personnel and contractors to familiarize themselves with environmental problems related to sulfur substances and to familiarize themselves with existing legal requirements	prevent the leakage of ,sulfur materials ,Risk Assessment Education and awareness Use of safety equipment Reference to guidelines and standards such as OHSAS 18001
Damage to the rig's equipment and structure	Gases can damage the equipment and structure of the drilling rig, for example, hydrogen sulfide can create an acidic state and cause damage to the .equipment	Use of safety equipment, continuous monitoring to detect leaks, up-to-date staff training, and implementation of safety procedures and .emergency protocols	Reviewing and updating methods and using appropriate equipment to deal with special gases (for example, using special equipment that is resistant to all .types of gases)

being poisonous	H ₂ S is a highly toxic gas and can be dangerous to humans even in small amounts. Contact with this gas can lead to breathing problems, heart problems, or even .death	Installation and commissioning of systems for managing and monitoring the amount of toxic gases, special safety equipment should be used, workers should receive regular safety training and awareness about identifying and preventing contact with .this gas	Risk Assessment Education and awareness Use of safety equipment Refer to guidelines and standards Perform routine maneuvers
Obstruction and corrosion of equipment inside and outside the well	H ₂ S gas can cause the formation of various deposits in drilling equipment, which can lead to their corrosion, blockage and improper performance. These things can cause technical problems and even irreparable .accidents	Special safety equipment should be used, workers should receive regular safety training and awareness about the detection and prevention of contact with this gas, and management and monitoring systems for the amount of toxic gases should be installed and .operated	Use of new technologies Emergency planning Proper ventilation Review and update methods and equipment Performing maintenance work on time

Discussion and conclusion

Various gases, including methane, carbon dioxide, and hydrogen sulfide, are commonly present in oil and gas well drilling operations and pose significant hazards to workers and equipment. These gases can cause explosions, financial losses, damage to workers' health, and damage to the environment. Therefore, identifying and dealing with these risks is very important. One of the effective ways to deal with the dangers of gases that leak from oil and gas wells during operations is to use appropriate safety equipment. These equipment include breathing masks, helmets, gloves, fixed and portable gas detectors and sensors, gas measurement and gas monitoring, which can help protect workers from the harmful effects of gases. In order to facilitate the presentation of the items mentioned in the towers, the service of dealing with toxic gases is provided by different companies. In addition, the use of advanced technologies such as continuous monitoring and wireless warning systems can help in the early detection of dangerous gases and lead to more safety measures. These technologies can act as warning systems for the risks of gas leaks and help to reduce the risks caused by them. This important point should be remembered that regular training and awareness of workers about the dangers of gas leaks in drilling operations and the methods of dealing with them are very important. Workers' awareness of the dangers associated with gases and how to use safety equipment and perform familiarization maneuvers with gas leakage conditions can help prevent accidents and serious injuries. Consequently, identifying, preventing, and dealing with gas leakage hazards in drilling operations requires a comprehensive and coordinated

approach that includes a combination of safety equipment, advanced technologies, and worker training. By implementing this approach, it is possible to help maintain safety and reduce risks in drilling operations and improve serious injuries through identification and management. In this article, the necessity and importance of training regarding the dangers of H₂S gas leakage in drilling rigs was investigated. H₂S gas leakage is recognized as one of the major hazards in the drilling industry, which has serious effects on workers' health and public safety. Trainings related to recognition, prevention, and performance in facing this gas are of great importance. In this article, the educational content required for drilling workers regarding H₂S gas was reviewed and strategies for identification, prevention, and performance in facing this risk were presented. The evaluation of the effectiveness of different trainings and the promotion of educational approaches were also investigated. As a result, proper and effective training regarding the dangers of H₂S gas can help improve safety performance in drilling rigs and reduce the effects of this gas on the health and safety of workers. This article emphasizes that training programs should be designed and implemented considering the real needs of workers and using effective training approaches in order to improve safety performance and create a safer work environment in the drilling industry.

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Identification of Suitable Wheat Cultivars for Deficit Irrigation Conditions in West Azerbaijan (Mahabad)

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Abstract

This study aimed to identify suitable wheat cultivars for deficit irrigation conditions in west Azerbaijan (Mahabad). The study was conducted in the agricultural station of this city from 2019-2020. It was carried out in a split plot-design in randomized complete blocks where deficit irrigation was the main factor. Furthermore, four levels and Simineh and Zarrin cultivars were studied as sub-factor levels. The results showed that decreasing the number of irrigation at the end of the growth period reduced the amount of production but the response of wheat cultivars to irrigation levels remained unchanged.

Keywords: Cultivars, Wheat, Deficit Irrigation

Introduction

Wheat is an important most-consumed food plant in the world. It belongs to the Poaceae family and Triticum genus, and its seeds are used to prepare bread, flour, pasta, baked foods and many other relevant products [1].

Wheat is a plant that grows in warm and cool regions and is widely cultivated in countries with good soil and desirable climatic conditions. It requires proper irrigation, fertile soil, sunlight, and the right temperature to grow and produce good seeds [2].

Wheat grains, commonly consumed in fried forms, contain important nutrients such as protein, fiber, vitamins, and minerals that are very important for the health of the human body.

The use of water-saving deficit irrigation regimes can be used as water management in increasing the area under cultivation and determining the cropping pattern, as well as determining the optimal cropping pattern. Deficit irrigation is considered an economically advantageous strategy in limited irrigation, aiming at maximum use of the unit volume of water [3].

Special steps should be taken to identify suitable wheat cultivars for deficit irrigation conditions as follows [4]:

1. ** Study and analysis of the environmental conditions of the site: ** First, you should carefully consider the environmental conditions of your site, including annual rainfall, temperature, soil, and altitude.
2. ** Consultation with local experts: ** It is better to consult with agricultural experts, local researchers, or agricultural universities to help you choose the right cultivars for deficit irrigation conditions.
3. ** Study and selection of drought-resistant cultivars: ** Cultivars that are genetically drought-resistant and capable of growing and producing under deficit irrigation conditions should be included in your selection.
4. ** Local tests: ** Before planting larger new cultivars, performing pilot or small tests in the area of interest can help you to check the yield and effects of different cultivars under the actual conditions of your location.
5. ** Continuous monitoring and care: ** Careful care of the plants during the growing season and optimal use of water and nutrients are essential for the selected cultivars for their best yield.

For deficit irrigation conditions in areas such as west Azerbaijan (Mahabad), wheat cultivars that can grow and yield well in these conditions can be suitable.

Most suitable wheat cultivars for deep-rooted deficit irrigation conditions are capable of a variety of environmental conditions and resistant to drought stress. Some suitable cultivars for these conditions are as follows:

1. ** Single-stem and storage cultivars that are suitable for deficit irrigation conditions. **
2. ** Drought-tolerant cultivars that are more able to tolerate drought than other cultivars. **

3. ** Cultivars that are not sensitive to irrigation restrictions and can benefit from a smaller amount of water. **

Theoretical Foundations and Research Background(Theoretical and literature review) :

Wheat is an important cereal crop that is considered a cereal plant from the Poaceae Family and Triticum Genus. It is one of the most important food sources in the world for the production of bread and other grain products [8].

The following conditions can be considered in planting wheat under deficit irrigation [10]:

1. ** Planting time **:

- Proper planning for wheat planting time is very important. For deficit irrigation conditions, planting is usually recommended when soil moisture is most appropriate.

2. ** Utilization of wheat masses **:

- The selection of drought-resistant and capable cultivars to meet the lower water requirement is one of the effective factors in planting wheat under deficit irrigation conditions.

3. ** Weed control **:

removal and control of weeds is critical for better utilization of soil and water resources.

4. ** Water management **:

- It is important to use water resources management methods such as drip irrigation and modern irrigation technologies for the optimal use of water in wheat cultivation under deficit irrigation.

5. ** Soil management **:

Soil hygiene, structural improvement, and the use of organic fertilizers are important for improving wheat growth under deficit irrigation conditions.

Better productivity of water resources and production of high-quality wheat under deficit irrigation conditions can be achieved by observing these points and using advanced planting methods.

Cold regions of east and west Azerbaijan, Ardabil, Hamedan, Kurdistan, Zanjan, Markazi, Tehran, Khorasan, Isfahan, Chaharmahal and Bakhtiari, Fars, Lorestan, Kermanshah, Kohgiluyeh and Boyer-Ahmad provinces are suitable for cultivation [5].

Danaei (2020) evaluated the effect of late water and late water cutting on the yield of 8 wheat cultivars. The results of this test indicate that the Chamran cultivar has the highest yield in both treatments and has a low coefficient of variation and environmental sensitivity indices [6].

In this regard, Feizabadi and Ghodsi (2020) evaluated the response of wheat lines and cultivars to drought stress and concluded that the average grain yield of the cultivars was 4777 kg ha⁻¹ in the control treatment and 4290 kg ha⁻¹ and 3397 kg ha⁻¹ in final water deficit and two final water deficit treatments, respectively. In terms of resistance or sensitivity to stress during grain filling, 17-V-C wheat cultivars were among the most resistant and Alamut cultivars were among the most sensitive [7].

According to a study by Mohammadi (2018), more than 800 thousand hectares of land under cultivation of irrigated wheat in cold regions of Iran (east and west Azerbaijan, Ardabil, Hamedan, Kurdistan, Zanjan, Markazi, Tehran, Khorasan, Isfahan, Chaharmahal and Bakhtiari, Fars, Lorestan, Kermanshah, and Kohgiluyeh and Boyer-Ahmad provinces) is dedicated to winter and interfacial wheat cultivation. These areas with an altitude of more than 1000 meters have relatively cold and long winters. The average absolute minimum temperature of these regions is less than -14°C per year and the number of freezing days is more than 90 days per year. Severe winter cold in most years, late spring cold in some cases, and some diseases, especially yellow rust, are the limiting factors of wheat production in these regions. Due to the limiting factors of production in these areas such as severe winter cold, late spring cold, important yellow rust disease, distribution, diversity of cropping conditions, and sensitivity of previous cultivars to yellow rust disease in recent years, identification of lines and introduction of new cultivars with high and stable yield potential and resistant to yellow rust is of particular importance. In this regard, Line C-83-7 with Alvand//NS732//Her pedigree, which has been created from internal hybridization programs and has gone through all stages of a breeding program in cold climate research stations, is introduced as a new Oroum cultivar [8].

According to Rezaei et al. (2013), suitable and modified cultivars play an effective role in increasing production. The Heidari cultivar is the result of the cold climate wheat breeding program of Iran that was created in 1996-1997 from the crossing of Ghk"s"/ Bow"s"/90Zhong87 with the Shiroodi cultivar in Karaj. In 1997-1998, the F1 generation was evaluated and its segregating generations were evaluated in Karaj in 1998-2003. In 2004-2008, this cultivar was studied in cold climate of Iran. In uniform adaptation experiments under normal irrigation and drought stress after the flowering stage, which were carried out in 12 cold climate research stations in 2006-2008, the Heidari cultivar with an average grain yield of 7145 kg/ha under normal conditions, and 6032 kg/ha under drought conditions was superior to the Shahriar cultivar with an average grain yield of 6413 kg/ha under normal conditions and 4507 kg/ha under drought conditions respectively. The highest grain yield (10600 kg ha⁻¹) was obtained in normal irrigation conditions in 2005-2006 from Hamedan Research Station. In research-comparative and research-extension projects, the Heidari cultivar was superior to control cultivars. This cultivar has an interfacial growth type. The mean weights of 1000 seeds were 41 g and 36 g in water and drought stress conditions. The seeds were hardy with bright yellow (amber yellow), the average plant height was 86 cm, the average number of days to flowering was 128 days, and the numbers of days to maturity were 176 and 165 days in water and drought conditions respectively. Furthermore, the average periods of seed filling were 48 and 37 days in water and drought conditions respectively. Heidari cultivar was resistant to yellow rust and was semi-sensitive to brown and black rust diseases. It was identified as good-quality wheat in terms of bakery quality indices [9].

Suitable wheat cultivars for deficit irrigation conditions

Wheat cultivars, which are suitable for deficit irrigation conditions, require less irrigation and are more resistant to drought stress. Some wheat cultivars suitable for deficit irrigation conditions are as follows [10] :

1. ** Basic cultivars such as: **
 ** Dizacombe **: High tolerance to drought stress
 ** Yumia: A good tolerance to drought stress
 ** Kambel: These types of wheat flowers tolerate the stress of drought periods.
2. ** New Cultivars **:
 ** Zarand: Wheat that consumes less water than conventional wheat cultivars.
 **DL 85-1 **: Wheat with good tolerance to drought stress.

3. ** Local cultivars **:

Some old local wheat cultivars may also have better tolerance to drought stress.

Early release of wheat is another important consideration given to low irrigation conditions. Cultivars, most of which can produce seeds in a shorter period, are more suitable for deficit irrigation areas.

Identification of suitable wheat cultivars for deficit irrigation conditions in West Azerbaijan (Mahabad)

In west Azerbaijan (Mahabad), which is a water deficit region in Iran, it is very important to use wheat cultivars that can tolerate drought stress and consume less water. Suitable cultivars are useful for deficit irrigation conditions in the Mahabad [9]:

1. ** Basic figures **:
 **Dizacombe **: This wheat species has a high tolerance to drought stress and requires less water consumption.
 ** Zarand **: A species suitable for low irrigation areas and consumes less water.
2. **New cultivars **:
 **DL 85-1 **: A species with good ability to tolerate drought stress and low water consumption.
 ** Sarv57 **: A species with some advantages of tolerance to drought stress and early maturity.
3. ** Local cultivars **:

There may be local and traditional wheat varieties in Mahabad with a better balance of local environmental barriers.

Research Method

An experiment was conducted at the agricultural research station of Mahabad during two cropping seasons, 2019 and 2020, to evaluate the response of wheat cultivars to deficit irrigation regimes. The 15-year mean results of the meteorological organization of the region indicated that the average annual temperature and precipitation were 10 °C and 295 mm, respectively. The experiment was arranged as the split plot in randomized complete block design in which deficit irrigation was the main factor at four levels (stemming+ heading, stemming+heading + flowering, stemming+ flowering, stemming+ heading+ flowering+ milk development as control), and Zarrin and Simineh as sub-factor levels. It should be noted that all levels of irrigation treatments were irrigated simultaneously at the beginning of the growing season and during the planting for uniform germination. To prepare a suitable seedbed for planting, the experiment plot was plowed and 100 kg/ha of pure phosphorus from the ammonium phosphate source and 70 kg/ ha of pure nitrogen from the urea source were applied to the ground and mixed with soil discs. Then, the experimental units were established. Each experimental unit consisted of 5 planting lines with a distance of 25 cm and a length of 4 meters. Grains were sown simultaneously with a density of 400 pcs/m². Soil walls and furrows were condensed before applying rammed irrigation treatments, and at the same time, a sufficient distance was considered to prevent water leakage from irrigation furrows to adjacent plots.

Results and discussion (yield and its components)

Number of grains per spike

Total irrigation treatment has the maximum number of grains per spike. Therefore, limited irrigation reduced the number of spikes per spike, but there was no significant difference between the first and second treatments (irrigation in stem elongation+ heading and irrigation in three stages of stem elongation+ heading+ flowering). It seems that the potential for seed formation in spikes is created from the pre-flowering stages (double ridge), however, irrigation in the post-stem elongation stages through the effect of fertilization can increase the number of seeds per spike.

1000-seed weight

The average 1000-seed weight of wheat is equal to the number of spikes per unit area.

Grain yield

Two methods can be used directly and indirectly to evaluate the differences between tolerant genotypes and water deficit conditions in wheat. The best method is direct measurement of production per unit area. The results of the combined analysis of variance indicated that the difference in grain yield between different irrigation levels was significant at a 99% confidence level.

Plant height

The effects of irrigation and cultivar on plant height showed that there was a significant difference between irrigation levels and cultivar in terms of this trait at a 1% probability level. The removal of irrigation stages at the end of the growth period reduced plant height by 95 cm.

Biological yield

The irrigation and cultivar stages had significant effects on biological yield. Obviously, by increasing the amount of water available to the plant, its vegetative growth is stimulated and it produces a large amount of foliage. According to Table 1, biological yield (9.14033 kg/ha) is maximum at the fourth level of irrigation applied at four times of field irrigation compared to other treatments. As grain yield is a part of biological yield, there is usually a positive correlation between the two

Table 1: Comparison of average plant height, grain yield, and 1000-seed weight

Experiment factors	Plant height (cm)	Number of grains per spike	Spike length (cm)	Number of tillers (per m ²)	1000-seed weight (g)	Grain yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Irrigation levels								
First	94.156 C	16.500 C	10.75 C	542.250 C	33.400 C	3601.553C	7906.797 C	45.100b
Second	95.313 C	17.000 C	10.787 C	545.313 C	33.788 C	376581 C	7996.128 C	43.441b
Third	101.156b	28.750b	12.837b	594.188b	39.031b	5392.597b	12436.369b	47.559a
Fourth	106.125a	33.563a	14.041a	659.844a	41.978a	6809.416a	14033.935a	48.531a
Cultivar								
Zarrin	94.875C	21.719	11.709 C	580.156	36.372b	4929.500a	10142.519a	48.00a
Simineh	95.781bc	23.781b	11.875C	580.500	36.541b	481.784a	10293.341b	46.4825ab
C-73-5	97.813b	24.688 a	12.097b	582.625	37.841a	4965.444a	11032.122a	45.341ab
C-73-20	100.281a	25.625a	12.738 a	596.313	37.444ab	4858.419a	10905.266a	44.456b

Discussion and Conclusion

The results of this study showed that the harvest index was affected by irrigation regimes and cultivars and there was a significant difference. The fourth irrigation level (four times irrigation) with the highest harvest index (53.48%) was in the highest rank and the second irrigation level (stem elongation+ flowering) with the lowest harvest index (44.43 %) was in the lowest rank. Furthermore, the amount of production relatively decreased by reducing the number of irrigation at the end of the growth period but the response of wheat cultivars to irrigation levels remained stable.

There is a need for wheat with special characteristics and resistance to deficit irrigation for deficit irrigation conditions in Mahabad in west Azerbaijan. Some suitable wheat cultivars for deficit irrigation conditions are as follows:

1. Diesel cultivar: It is one of the deficit-irrigated cultivars that can grow well in different climatic conditions. This cultivar usually does not encounter a delay in growth and germinates quickly.
2. Serus cultivar: It is also suitable for deficit irrigation conditions. This cultivar has strong stems and deep roots that can extract the required moisture from the soil depth. It is usually well adapted to arid climate conditions.
3. Bami cultivar: This cultivar is also suitable for deficit irrigation conditions. It has characteristics such as resistance to drought stress and the ability to produce high-quality grain. This cultivar is also fast growing and usually adapts well to deficit irrigation conditions.
4. Hemmat cultivar: This cultivar is also one of the suitable cultivars for deficit irrigation conditions. It has characteristics such as resistance to drought stress and the ability to produce high-yield grain.

It is important to consult local agricultural authorities to select the right cultivar for deficit irrigation conditions and keep in mind that other factors such as soil and climatic conditions can also affect wheat growth and yield.

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Investigating Sustainable Design According to Sustainability Model to Achieve Less Consumption Mechanism and More Productivity from Nature

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Abstract

Sustainable architecture as one of the newest methods of growth and promotion is based on climatic characteristics. In this type of architecture, the building not only adapts itself to the climatic conditions of the area, but also establishes a reciprocal relationship with it. Principles that must be followed in order for a building to be classified as a sustainable building: Energy conservation, harmony with the climate, reduction of the use of non-renewable resources, and meeting the needs of residents, all of which should be implemented in a complete process leading to the construction of a healthy environment, in this regard, in this research, according to the goal of achieving a mechanism of less consumption and more productivity from nature to understand the sustainable design process, it is possible to understand the sustainable design process. The triple model of sustainability was used and the principles and factors that should be considered in sustainable design were investigated in this study. And the results are that in order to achieve a mechanism of less consumption and more productivity from nature, you can use smarter methods to exploit natural resources instead of using them indiscriminately.

Keywords: sustainable architecture, sustainable design, triple model of sustainability, productivity from nature

1. Introduction

Humanity has always been looking for a safe environment for its survival and comfort, and to this day, it has taken every opportunity to achieve this goal. He has realized that technology must be redefined in a different way. Otherwise, they and future generations will be victims of it. It reveals the compulsion of strategies to reduce energy consumption through climate sustainability approaches.

Therefore, if the construction of housing does not have a sustainable trend, no society can achieve sustainable development, which is necessary to deal with such problems, and where architecture in construction and use has played a large role in the emission of carbon dioxide gas, the total emission of which is estimated to be more than 50%. Architecture in general includes cities, buildings and housing, and human activities such as energy consumption and materials, etc Minimizing waste and the activities that link it to the continued protection of natural resources can produce many harmful gases.. In order to understand the sustainable design process, we only use a simple three-loop diagram to represent the dependencies and relationships of different parts of sustainability (Figure 1).

In Figure 1, sustainability includes two parts: the first part is the economy, society, environment, and architecture. Each section has prerequisite factors, which are shown below.

Environment: Orientation, Climate, Infrastructure, Light/Space/Air Conditioning, Energy/Water.

Economy: Value Added, Flexibility, Business Reality, Lifespan.

Society: Culture, Social Interests, People, Health, and Welfare.

Architecture: Form and Function, Identity, Structure, Materials, Innovation.

And in the second part, energy conservation and respect for nature and architecture and the welfare and health of the community in the complex constitute sustainability in architecture [4].

Therefore, architecture is not merely an activity that correctly balances the internal considerations of the building. The building itself enters into a complex unit in which the successful outcome of the project depends on the achievement of a dynamic interaction and harmony between the architecture and the surrounding environment, which is also illustrated by the triple model in Figure 1.

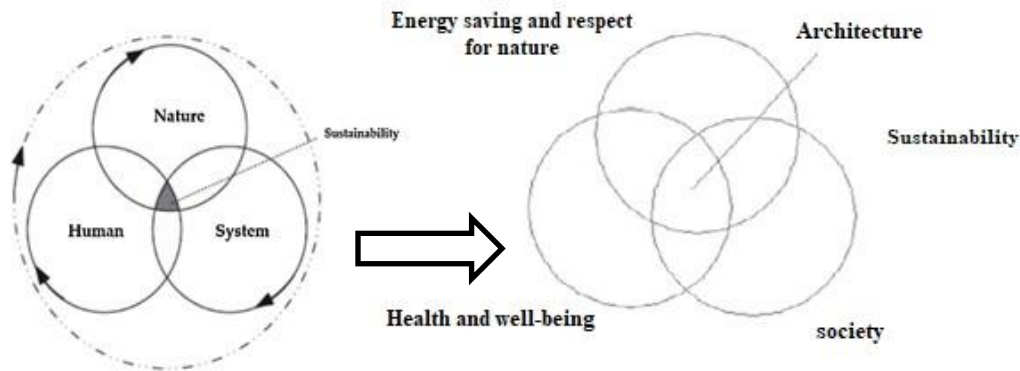


Figure 1. The Triple Model of Sustainability

2. Research Methodology

This research uses a descriptive-analytical method to investigate sustainable design according to the triple model of sustainability in order to achieve a mechanism of less consumption and more productivity from nature.

3. Sustainable Design in Architecture

Sustainability means continuity, progress, and adaptation to renewable resources. Usually, sustainability is seen as a key issue in the economy and society. Now, the challenge of climate change leads us to introduce sustainability in architecture. As we know, architecture is about building a living space for human life and progress, as well as addressing nature and the earth's resources from a sustainable and global perspective.. Sustainable architecture does not have to be exclusively research on reducing carbon dioxide emissions. Rather, it is necessary to look at sustainability from a general perspective that takes into account financial, cultural, and social issues, as well as ecological and environmental ideals.

Since conventional energy sources produce carbon dioxide, the first step is to find ways to reduce the building's energy consumption, which means minimizing the need for anything that requires energy, such as air conditioning, mechanical ventilation, artificial lighting, and so on. The second step should be to exploit renewable energy sources wherever possible in planning future master plans.

Sustainability is a system that is constantly growing and evolving due to sustainable architecture and its surrounding environment. Sustainable design based on the general method can make people's welfare, environmental considerations, technological possibilities and nature itself more connected, which is the basis of a sustainable future. Sustainable design is the thoughtful collaboration of architecture with structural engineering, and mechanics. In addition to the common design factors such as beauty, proportion, texture and light, and the facilities that must be considered, the design group should pay attention to many factors such as the environment, the economy, and consider its primary principles, which are as follows:

1) 2) Climate and climate, 3) Covering buildings, 4) Reviving cultural and regional identity, 5) Volume of buildings and placement of interior spaces, 6) Building materials, 7) Estimating human needs, 8) Coordination with the site, 9) Paying attention to all laws at the same time.. In the construction industry, the proposed framework is based on the three principles of sustainable architecture.

The usual practice of architects in sustainable architecture is to minimize the environmental impact of buildings by selecting environmental criteria that are used to influence the design process. The Breim Act , the UK Sustainable Building Regulations published in 2006, describes the environmental factors involved in complying with

environmental regulations. We believe that this explanation is a better description of environmental considerations in sustainable design. Also, it is better to use economic and social factors in the sustainable design process.

Table 1. Factors Affecting Sustainable Design

Categories	Factors
Energy and CO2 emissions	<ul style="list-style-type: none"> • Greenhouse gas emissions in apartments • Building Texture, Drying Space • Indoor and outdoor lighting • White goods with energy labels • Cyclical storage
Water	<ul style="list-style-type: none"> • Cost of Internal Water • External Water Costs
Materials	<ul style="list-style-type: none"> • Environmental Impact of Materials • Finding Reliable Sources of Materials – Primary Building Materials
Waste	<ul style="list-style-type: none"> • Storage of non-recyclable waste and recycling of household waste • Construction Waste Management • Storing organic matter and using it as fertilizer
Pollution	<ul style="list-style-type: none"> • The potential of insulation materials in global warming • NOx Emission
Health and well-being	<ul style="list-style-type: none"> • Daylight • Sound insulation • Private space and living space
Land use and ecology	<ul style="list-style-type: none"> • Ecological value of the site • Ecological Enhancement • Preserving the ecological features of the land • Changes in the ecological value of the site
microclimate	<ul style="list-style-type: none"> • Vegetation • Wind Reduction/Ducting • Topography
Community	<ul style="list-style-type: none"> • Social diversity • Cultural heritage • Low-impact dynamics • Law & Regulations, Texture

3. Sustainable Design Principles

In the modern era, design professions choose the sustainable design method to approach sustainability in architecture. Based on the theory expressed by the three-ring model of sustainability and the holistic method, the basic principles of sustainable design to achieve a mechanism of less consumption and more efficiency from nature are described in Table 2.

to Achieve Less Consumption and More Efficiency from Nature Table 2: Fundamentals of Sustainable Design

Respect for nature	1
Meeting human needs and progress	2
Full exploitation of natural resources	3
Using local energy as an energy source using local materials and workers	4

3.1. Sustainability based on respect for nature

Our understanding of sustainable development has usually been economic and social development that maintains growth within the permissible limits of global resource exploitation and environmental pollution . Nature helps drive where holism is the basis of sustainable building design.

3.2. Meeting Human Needs and Development

Sustainable development should be viewed from the perspective of meeting human needs and progress. In every case, it is not possible to destroy the ecological environment or ignore human needs in the name of protecting the ecological environment.

3.3. Exploitation of natural resources

Emphasis on energy efficiency, full exploitation and recyclable use of resources is important, which achieves rules in the design process.

The Law of Reduction: This law requires a reduction in the need for energy, water, land, and materials used in buildings. It may be as simple as to focus on energy consumption for water heating, summer ventilation, and lighting in design. Active systems, the use of clean and renewable systems, and the selection of sustainable and water materials that can be considered in the design. The production of sustainable materials consumes less energy and is not harmful to the environment.

Recycling Law: In sustainable design, recyclable materials should be selected as building materials wherever possible. Currently, rainwater and wastewater recovery systems are examples of this type of use.

The law of reuse: The permanent usefulness of most building materials should be considered in the design process, which means that at the end of the useful life of the materials, they should be used as after-use resources and given a new life by using them in the form of new materials and by using ready-made parts made of recycled materials in the form of new materials and ready-made parts or for other uses.. The construction method of any new device should be in order to maximize the efficiency of the building texture in order to conserve resources in future operations. In this context, existing building reserves should be considered as an important resource.

The Law of Renewable Resources: In sustainable design, renewable resources should be used as widely as possible . Renewable energy is a source of renewable resources that cannot be quickly replaced. Many renewable energies such as wind energy, photovoltaic systems, solar thermal systems for heating water, heat pumps with a ground source for heating and cooling, etc. have been increasingly used in recent projects [13-14].

3.4 Using the available energies as a source of energy using local materials and workers

This is the principle of location-based design, which means designing a design based on the principles of sustainability using local energy as an energy source, using local materials and workers in construction, and

respecting the region and culture. Adopting a passive design strategy is recommended. Usually, our understanding of the principles of passive design is the creative use of building planning to connect buildings to their environment and climate. [15].

Considerations related to the construction of buildings should be considered in sustainable design. Based on the functional analysis and the main possibilities for the flexibility of buildings and their surroundings at a certain point in time, it is important to give a human spirit to the built environment by designing buildings that are in harmony with their texture and strengthening the sense of locality.

4. Conclusion

Sustainability architecture is defined by the sustainable development of the economy, society, environment, and at the same time architecture itself. Sustainability in architecture originates from sustainable design, which is a dynamic and living process. To understand the mechanism of the sustainable design process, the triple model of sustainability can be used. The principles and factors that should be considered in sustainable design have been investigated in this paper. To achieve a mechanism of less consumption and greater productivity from nature, you can use smarter ways to exploit natural resources instead of using them indiscriminately. And by optimizing processes and using sustainable technologies, you can increase resource efficiency. For example, using solar systems to generate energy such as solar panels. And the conservation and protection of natural resources and the environment plays an important role in achieving sustainability. This includes preserving forests, reducing air and water pollution, and supporting biodiversity. According to these methods and according to the triple sustainability model, you can improve the sustainable design and achieve the mechanism of lower consumption and higher efficiency than nature. Therefore, designing systems and processes in a way that provides flexibility and diversity in the face of environmental and economic changes can contribute to sustainability. For example, the use of flexible production systems that can be adapted to different conditions and the establishment of cooperation with different individuals, organizations, and communities in order to achieve sustainable goals can have a great impact. exchange of knowledge, resources, and experiences.

Due to these methods, you can implement a sustainable design that contributes to the mechanism of lower consumption and higher productivity than nature, achieving economic, social, and environmental sustainability.

In this regard, sustainable design, which is very different from traditional design, may be focused design, high-efficiency design, smart design, appropriate design, and interdisciplinary cooperation that has been moving forward. Countries like China pay a lot of attention to buildings with minimal greenhouse gas emissions. The National Green Building Assessment Standard was published in 2006, and many green buildings were built, among which the China Expo Mansion in Shanghai, China, which was built in 2010, and the twin towers connected to the pool in Singapore in 2015. The texture of this residential complex is reminiscent of the structure of the mountainside and provides good ventilation and lighting due to the fact that it has a suitable and multiple orientations. And the sustainable mixed-use complex was built by Vincent Calbat in Egypt in 2019. These complexes have green roofs and are covered with solar panels to absorb maximum energy from the environment, examples of these buildings are examples.

¹ GB/T50328-2006

¹ Expo's China

¹ BISHAN CENTRAL CONDOMINIUM

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Comparative Analysis of Traditional Deterministic Evacuation Simulations vs. Indeterministic Cognitive Agent-Based Simulations

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Abstract

Traditional evacuation modeling tools, such as Pathfinder, utilize deterministic algorithms to simulate human crowd behavior during emergencies. While these methods offer computational efficiency and structured predictability, they often fall short in capturing the complex, stochastic nature of human behavior in crowds. In contrast, cognitive agent-based simulations, leverage behavior trees, physical animations, actor-environment interactions, and simulated line-of-sight to create more dynamic and realistic representations of crowd movements and decision-making processes. This study systematically evaluates both approaches by setting up identical evacuation scenarios within Pathfinder and Unreal Engine, analyzing the performance, accuracy, and realism of each method. Quantitative metrics such as evacuation time, path efficiency, and collision rates are assessed alongside qualitative observations of emergent behaviors and adaptability to unforeseen events. The findings indicate significant differences in the fidelity and applicability of deterministic versus indeterministic models, highlighting the strengths and limitations of each. This research contributes to the field of architectural design and safety planning by providing insights into the efficacy of advanced simulation tools. It underscores the potential of cognitive agent-based models in enhancing the realism and reliability of evacuation simulations, ultimately informing better design and safety strategies in complex architectural environments.

Keywords: Deterministic Simulation, Indeterministic Simulation, Cognitive Agent-Based Modeling, Unreal Engine, Pathfinder, Evacuation Simulation, Human Behavior Modeling, Stochastic Processes, Safety Planning, Behavior Trees, Physical Animations, Collision Detection, Real-Time Simulation, Line-of-Sight Simulation

Introduction

1. Background and Motivation

The field of architectural design and safety planning has long relied on simulation tools to predict human behavior during emergency evacuations. Traditional deterministic evacuation simulation tools, such as Pathfinder, have been extensively used to model crowd dynamics and optimize evacuation strategies. These tools employ deterministic algorithms that assume uniform behavior patterns, providing structured and predictable outcomes. However, the complexity of human behavior, particularly under stress, especially in crowds, often results in unpredictable and stochastic actions that deterministic models struggle to accurately represent (Kuligowski, Peacock, & Hoskins, 2010).

Recent advancements in computational technology and gaming engines, such as Unreal Engine and Unity, offer new opportunities to enhance the realism of human behavior simulations. These engines support cognitive agent-based modeling, which incorporates behavior trees, physical animations, actor-environment interactions, and simulated line-of-sight. This approach allows for the creation of more dynamic and realistic simulations, capturing the stochastic nature of human behavior during evacuations (Epic Games, 2021; Bonabeau, 2002).

2. Research Objectives

This paper aims to conduct a comprehensive comparative analysis of traditional deterministic evacuation simulations and indeterministic cognitive agent-based simulations using Unreal Engine. The specific objectives of this research are:

- To evaluate the accuracy and realism of deterministic simulations in Pathfinder compared to cognitive agent-based simulations in Unreal Engine.
- To assess the computational efficiency and resource utilization of both simulation methods.
- To identify the strengths and limitations of deterministic and indeterministic approaches in modeling human crowd behavior.
- To explore the implications of these findings for architectural design and safety planning.

3. Significance of the Study

The significance of this study lies in its potential to bridge the gap between traditional deterministic simulations and modern cognitive agent-based approaches. By systematically comparing these methods, this research provides valuable insights into the effectiveness of each approach in accurately modeling human behavior during evacuations. The findings of this study can inform architects, safety planners, and simulation tool developers about the best practices and potential improvements in evacuation modeling. Ultimately, this research aims to contribute to the development of safer and more efficient architectural designs and evacuation strategies.

4. Overview of the Paper

This paper is structured as follows:

- **Literature Review:** An overview of existing research on deterministic and cognitive agent-based simulations, including key algorithms and approaches used in each method. The review also highlights previous comparative studies and identifies gaps in current research.
- **Methodology:** A detailed description of the simulation frameworks used in Pathfinder and Unreal Engine, including scenario design, parameter selection, and data collection methods. This section also outlines the analytical techniques used to compare the two approaches.
- **Implementation in Pathfinder:** An in-depth explanation of the deterministic simulations conducted in Pathfinder, covering the algorithms used, model setup, execution, and data collection process.
- **Implementation in Unreal Engine:** A comprehensive description of the indeterministic simulations conducted in Unreal Engine, including cognitive agent modeling, behavior trees, physical animations, line-of-sight simulation, and collision detection.
- **Comparative Analysis:** A comparison of the two simulation methods based on accuracy, realism, computational efficiency, and resource utilization. This section presents both quantitative and qualitative findings.
- **Case Studies:** Real-world applications of the simulation methods, including scenario-based comparative results and lessons learned from case studies.
- **Discussion:** Insights from the comparative analysis, theoretical and practical implications, limitations of the study, and recommendations for future research.
- **Conclusion:** A summary of key findings, contributions to the field, and final thoughts.
- **References:** A comprehensive list of cited works.

Literature Review

- I. Traditional Deterministic Evacuation Simulations
- A. Overview of Pathfinder and Similar Tools

Pathfinder is a widely used evacuation simulation software that employs deterministic algorithms to model human crowd behavior during emergencies. It provides a user-friendly interface for creating detailed building models and simulating evacuation scenarios. Pathfinder's deterministic approach ensures that given the same initial conditions, the simulation will produce the same results every time, offering consistency and repeatability in the analysis of evacuation strategies (Thunderhead Engineering, 2019).

Other tools similar to Pathfinder include Revit, which integrates with building information modeling (BIM) to simulate occupant movement and egress paths, and STEPS (Simulation of Transient Evacuation and Pedestrian movements), which models pedestrian flow using deterministic principles. These tools are essential in architectural design and safety planning, providing insights into potential bottlenecks and optimizing evacuation routes.

B.Key Deterministic Algorithms and Approaches

Deterministic evacuation simulations rely on predefined rules and algorithms to model human behavior. These algorithms typically include shortest path calculations, crowd density thresholds, and predefined behavior patterns (Kuligowski, Peacock, & Hoskins, 2010). For instance, Pathfinder uses a combination of agent-based modeling and flow-based techniques to simulate individual movement and crowd dynamics (Thunderhead Engineering, 2019).

Key approaches include:

- **Shortest Path Algorithms:** Calculate the most efficient routes for occupants to exit a building (Helbing, Farkas, & Vicsek, 2000).
- **Density Thresholds:** Define maximum allowable crowd densities to prevent bottlenecks and ensure smooth evacuation (Kuligowski et al., 2010).
- **Behavioral Rules:** Predefine how occupants react to various stimuli, such as alarms or visible smoke (Gwynne et al., 1999).

These deterministic methods offer simplicity and computational efficiency but may fail to capture the nuanced and often unpredictable nature of human behavior in real-life emergencies.

II. Cognitive Agent-Based Simulations

A. Overview of Unreal Engine and Similar Tools

Unreal Engine, primarily known for its use in gaming, has emerged as a powerful tool for simulating complex human behaviors in various environments, including emergency evacuations. Unlike traditional deterministic tools, Unreal Engine supports cognitive agent-based modeling, which incorporates behavior trees, physical animations, and actor-environment interactions to create more realistic simulations (Epic Games, 2021).

Other similar tools include Unity, another gaming engine that supports advanced physics and behavior modeling, and AnyLogic, which combines agent-based, discrete event, and system dynamics modeling to simulate complex systems. These tools allow for the creation of highly detailed and dynamic simulations that can account for the stochastic nature of human behavior.

B. Key Indeterministic Algorithms and Approaches

Indeterministic simulations use stochastic processes to model human behavior, introducing variability and unpredictability into the simulation. Key algorithms and approaches include:

- **Behavior Trees:** Define hierarchical decision-making processes for agents, allowing for complex and adaptable behavior patterns (Isla, 2005).
- **Physical Animations:** Simulate realistic human movements and interactions with the environment (Epic Games, 2021).

- Actor-Environment Interactions: Enable agents to perceive and respond to their surroundings dynamically, using line-of-sight and collision detection (Epic Games, 2021).

These approaches allow for the modeling of emergent behaviors, where agents' interactions can lead to unexpected outcomes, providing a more realistic representation of human behavior during evacuations (Bonabeau, 2002).

III. Comparative Studies in Evacuation Simulation

A. Previous Comparative Analyses

Previous studies have compared deterministic and indeterministic evacuation simulations, highlighting the strengths and limitations of each approach. For example, Kuligowski et al. (2010) compared the performance of deterministic models like Pathfinder with more complex cognitive agent-based models, finding that while deterministic models are efficient, they often lack the ability to capture the full range of human behaviors observed in real evacuations.

Studies by Pelechano and Malkawi (2008) and Gwynne et al. (1999) have also highlighted the importance of incorporating stochastic elements to improve the realism and accuracy of simulations. These studies emphasize that while deterministic models provide a solid foundation, integrating indeterministic elements can significantly enhance the predictive power of evacuation simulations.

B. Gaps in Current Research

Despite significant advancements, several gaps remain in the current research. One major gap is the integration of deterministic and indeterministic models to leverage the strengths of both approaches. Additionally, there is a need for more empirical validation of cognitive agent-based simulations to ensure their accuracy and reliability in real-world scenarios (Kuligowski et al., 2010).

Another gap is the limited exploration of user interface and usability factors in simulation tools, which can affect their adoption and effectiveness in architectural design and safety planning (Pelechano & Malkawi, 2008). Addressing these gaps could lead to more comprehensive and effective evacuation simulation tools, ultimately improving safety and efficiency in architectural spaces.

Methodology

I. Simulation Frameworks

The methodology for this study involves setting up and running evacuation simulations using both deterministic and indeterministic approaches. The deterministic simulations are conducted using Pathfinder, a widely recognized evacuation modeling tool. In contrast, the indeterministic simulations are executed within Unreal Engine, a versatile gaming engine capable of simulating complex human behaviors. This section outlines the setup procedures, scenario designs, parameter selections, and data collection methods employed in both simulation frameworks.

II. Setup in Pathfinder

Pathfinder is selected for its robust capabilities in modeling deterministic evacuation scenarios. The setup process involves the following steps:

- Modeling the Environment: A detailed architectural model of the evacuation environment is created within Pathfinder, incorporating all relevant structural elements, exits, and obstacles.
- Defining Occupant Characteristics: Occupant profiles are established with predefined behavior patterns, movement speeds, and response times based on typical evacuation scenarios (Thunderhead Engineering, 2019).
- Setting Simulation Parameters: Key parameters such as exit availability, crowd density thresholds, and movement algorithms are configured to reflect realistic evacuation conditions (Kuligowski, Peacock, & Hoskins, 2010).

The simulation is then executed, with Pathfinder's deterministic algorithms calculating the most efficient evacuation routes and predicting the movement of occupants based on the predefined parameters.

III. Setup in Unreal Engine

Unreal Engine is utilized for its advanced capabilities in modeling indeterministic, cognitive agent-based simulations. The setup involves several steps:

- **Environment Modeling:** A detailed 3D model of the evacuation environment is created within Unreal Engine, using tools such as Blender or Unreal Engine's built-in modeling capabilities (Epic Games, 2021).
- **Agent Behavior Trees:** Cognitive agents are defined using behavior trees, which outline hierarchical decision-making processes and enable dynamic, adaptable behaviors (Isla, 2005).
- **Physical Animations and Interactions:** Realistic human movements are simulated using Unreal Engine's animation tools, and physical interactions between agents and the environment are modeled using collision detection and physics engines (Epic Games, 2021).
- **Line-of-Sight Simulation:** Agents' ability to perceive their surroundings is simulated using line traces, which allow them to react to visible exits, obstacles, and other agents dynamically.

The simulation runs with agents interacting stochastically based on their individual behavior trees and the dynamic environment, providing a more realistic representation of human behavior during evacuations.

IV. Simulation Scenarios and Parameters

A. Scenario Design

To ensure a comprehensive comparison, identical evacuation scenarios are designed for both Pathfinder and Unreal Engine simulations. These scenarios include:

- **Building Layout:** A multi-story office building with multiple exits, stairwells, and common areas is modeled to represent a typical high-density environment.
- **Occupant Distribution:** A heterogeneous mix of occupants with varying speeds, behaviors, and responses is used to mimic real-world conditions.
- **Emergency Conditions:** Scenarios include common emergency situations such as fire alarms, visible smoke, and blocked exits to test the adaptability and effectiveness of each simulation method.

B. Parameter Selection and Justification

Key parameters are selected based on their relevance to evacuation dynamics and their ability to impact the simulation outcomes. These parameters include:

- **Occupant Speed:** A range of walking speeds is used to represent different ages and physical abilities (Kuligowski et al., 2010).
- **Response Time:** Variations in initial response times are incorporated to reflect differences in occupants' awareness and reaction times.
- **Exit Availability:** Different scenarios with varying numbers of available exits are tested to assess the robustness of the evacuation strategies.
- **Crowd Density:** Maximum allowable crowd densities are defined to prevent bottlenecks and ensure smooth evacuation flows.

The selection of these parameters is justified by their critical role in influencing evacuation outcomes and their representation of realistic conditions.

V. Data Collection and Analysis Methods

A. Data Metrics and Indicators

Data is collected on several key metrics to evaluate the performance of each simulation approach:

- Evacuation Time: The total time taken for all occupants to evacuate the building.
- Path Efficiency: The average distance traveled by occupants compared to the shortest possible routes.
- Collision Rates: The frequency and severity of collisions between agents and with obstacles.
- Behavioral Adaptability: The ability of agents to adapt to changing conditions and obstacles.

These metrics provide a comprehensive assessment of the accuracy, realism, and efficiency of each simulation method.

B. Analytical Techniques

The collected data is analyzed using both quantitative and qualitative techniques:

- Statistical Analysis: Quantitative data on evacuation times, path efficiency, and collision rates are statistically analyzed to identify significant differences and trends between the two simulation methods.
- Behavioral Analysis: Qualitative observations of agent behaviors, including their responses to changing conditions and emergent behaviors, are analyzed to assess the realism and adaptability of each approach.

The combination of these analytical techniques ensures a thorough and nuanced comparison of deterministic and indeterministic simulation methods.

Implementation in Pathfinder

I. Detailed Description of Deterministic Simulations

Pathfinder is employed for its capability to perform deterministic simulations of evacuation scenarios within an 8-level hospital 3D model. Deterministic simulations in Pathfinder rely on predefined rules and algorithms to predict occupant behavior during evacuations. This approach ensures consistency and repeatability, providing valuable insights into potential evacuation issues and optimizing emergency response strategies.

The hospital model includes various departments such as emergency rooms, patient wards, operating theaters, and common areas like lobbies and cafeterias. Each floor is equipped with multiple exits and stairwells, and the model accounts for different types of occupants, including patients with mobility issues, medical staff, and visitors. The deterministic approach in Pathfinder uses a fixed set of parameters and behavior rules to simulate the evacuation process, ensuring that the results are replicable under the same initial conditions (Kuligowski, Peacock, & Hoskins, 2010).

II. Algorithms Used for Evacuation

Pathfinder employs a combination of agent-based and flow-based algorithms to model occupant movement and evacuation dynamics. The primary algorithms used include:

- Shortest Path Calculation: Pathfinder uses Dijkstra's algorithm to compute the shortest evacuation routes for each agent. This ensures that occupants take the most efficient paths to the nearest exits, minimizing evacuation time (Helbing, Farkas, & Vicsek, 2000).

- **Density-Dependent Movement:** The model incorporates density-dependent movement algorithms that adjust occupant speeds based on local crowd density. This prevents unrealistic high-speed movement in crowded areas and simulates congestion effects accurately (Gwynne, Galea, Lawrence, & Filippidis, 1999).
- **Predefined Behavior Patterns:** Occupants in the simulation follow predefined behavior patterns, such as responding to alarms, moving towards exits, and assisting others if necessary. These behaviors are based on empirical data from real-world evacuation studies (Kuligowski et al., 2010).

These algorithms work together to create a realistic and reliable simulation of the evacuation process, capturing essential aspects of human behavior and movement dynamics.

III. Model Setup and Execution

The setup and execution of the evacuation model in Pathfinder involve several key steps:

- **3D Model Integration:** The 8-level hospital model is imported into Pathfinder, ensuring accurate representation of all structural elements, exits, and pathways. Detailed modeling of each floor includes stairwells, corridors, and room layouts to reflect the real-world environment accurately.
- **Occupant Profiling:** Occupant profiles are created to represent the diverse population within the hospital. Profiles include parameters such as movement speed, response time to alarms, and specific needs for patients with mobility impairments. These profiles ensure that the simulation reflects the varied behaviors and abilities of real occupants.
- **Scenario Configuration:** Multiple evacuation scenarios are configured to test different emergency situations. Scenarios include variations in exit availability, presence of obstacles (e.g., smoke, debris), and different starting locations for occupants. This comprehensive scenario setup allows for a robust analysis of the hospital's evacuation plan.
- **Execution of Simulations:** The configured scenarios are executed, with Pathfinder's deterministic algorithms calculating the evacuation routes and movements for each occupant. The simulation runs in real-time, providing a visual representation of the evacuation process and capturing detailed data on occupant movements and interactions.

IV. Data Collection Process

Data collection during the simulations is crucial for evaluating the performance and effectiveness of the evacuation plans. The following data metrics are collected and analyzed:

- **Evacuation Time:** The total time taken for all occupants to evacuate the building is recorded for each scenario. This metric is essential for assessing the efficiency of the evacuation plan.
- **Path Efficiency:** The efficiency of the evacuation paths taken by occupants is evaluated by comparing the actual paths to the shortest possible routes. Deviations from the optimal path indicate potential issues in the evacuation plan.
- **Crowd Density:** The simulation monitors crowd density at various points in the building, identifying potential bottlenecks and areas of congestion. This data helps in understanding the impact of crowd dynamics on evacuation efficiency.
- **Occupant Interactions:** Interactions between occupants, such as helping behavior and collision events, are recorded. These interactions provide insights into the social dynamics of the evacuation process.

The collected data is analyzed using statistical methods to identify trends and evaluate the performance of the evacuation strategies. The analysis helps in identifying strengths and weaknesses in the current evacuation plan and provides recommendations for improvements.

Implementation in Unreal Engine

I. Detailed Description of Indeterministic Simulations

Unreal Engine is utilized for its advanced capabilities in indeterministic, cognitive agent-based simulations, providing a dynamic and realistic representation of human behavior during evacuations. The simulation framework leverages behavior trees, physical animations, line traces for simulated eyesight, and collision detection to model complex interactions within an 8-level hospital 3D environment. This approach aims to capture the stochastic nature of human behavior, offering insights into how individuals and groups might react in emergency scenarios.

II. Cognitive Agent Modeling

Cognitive agent modeling in Unreal Engine involves creating virtual agents that mimic human decision-making processes. Each agent is equipped with a behavior tree, a hierarchical structure that determines their actions based on various conditions and stimuli. Behavior trees allow for flexible and adaptive behaviors, enabling agents to respond dynamically to changes in their environment (Isla, 2005).

For instance, an agent might follow a sequence of actions such as detecting an alarm, identifying the nearest exit, and navigating towards it while avoiding obstacles and other agents. This method allows for the simulation of complex, emergent behaviors that are characteristic of real human crowds in emergency situations (Bonabeau, 2002).

III. Behavior Trees and Physical Animations

Behavior trees in Unreal Engine provide a framework for defining agent behaviors in a modular and scalable way. They consist of nodes that represent actions, conditions, and control flow constructs such as sequences and selectors (Isla, 2005). This modularity allows for the creation of sophisticated behaviors without the need for extensive scripting.

Physical animations enhance the realism of agent movements, ensuring that actions such as walking, running, and navigating obstacles are depicted accurately. Unreal Engine's advanced animation system enables smooth transitions between different states and actions, contributing to a more immersive simulation experience (Epic Games, 2021).

IV. Simulated Eye Sight and Line Traces

Simulated eyesight in Unreal Engine is achieved using line traces, which allow agents to perceive their surroundings and make decisions based on what they "see." Line traces are cast from the agent's viewpoint, detecting obstacles, exits, and other agents within their line of sight (Epic Games, 2021). This capability is crucial for simulating realistic behavior, as it enables agents to react to visible threats and navigate their environment more effectively.

For example, an agent might use line traces to identify a clear path to an exit or detect a blocked route and choose an alternative path. This approach mirrors the way humans use vision to navigate complex environments, adding a layer of authenticity to the simulation (Chen, 2015).

V. Collision Detection and Physical Interactions

Collision detection is an essential component of realistic simulations, ensuring that agents interact physically with their environment and with each other. Unreal Engine's physics engine provides robust collision detection and response capabilities, enabling agents to avoid obstacles, push through crowds, and experience realistic physical interactions (Epic Games, 2021).

Physical interactions are modeled to account for various factors such as force, mass, and friction, ensuring that movements and collisions are depicted accurately. This level of detail is crucial for understanding how crowd dynamics influence evacuation processes and identifying potential bottlenecks and hazards (Mainzer, 2015).

VI. Data Collection Process

The data collection process in Unreal Engine simulations involves capturing detailed metrics on agent behavior and evacuation dynamics. Key data points include:

- **Evacuation Time:** The total time taken for all agents to evacuate the building, providing a measure of the overall efficiency of the evacuation process.

- **Path Efficiency:** The efficiency of the routes taken by agents, measured by comparing actual paths to the shortest possible routes.
- **Collision Events:** The frequency and severity of collisions between agents and with obstacles, offering insights into crowd density and movement patterns.
- **Behavioral Adaptability:** The ability of agents to adapt to changing conditions, such as blocked exits or sudden obstacles.

Data is collected through Unreal Engine's built-in logging and analytics tools, which record detailed information on agent movements, interactions, and decision-making processes. This data is then analyzed to evaluate the performance and realism of the cognitive agent-based simulations, providing a comprehensive understanding of evacuation dynamics in complex environments (Weyns, 2005).

Comparative Analysis

I. Comparison Criteria

The comparative analysis between deterministic simulations using Pathfinder and indeterministic simulations using Unreal Engine focuses on several key criteria: accuracy and realism, computational efficiency, and resource utilization. These criteria provide a comprehensive assessment of the performance and applicability of each simulation method in the context of evacuation modeling for an 8-level hospital building.

II. Accuracy and Realism

Accuracy and realism are evaluated based on evacuation time, path efficiency, collision events, and behavioral adaptability. The following tables present the quantitative data collected from both simulation methods.

Table 1: Pathfinder Simulation Results

Floor	Evacuation Time (s)			Path Efficiency (%)	Collision Events (count)	Behavioral	Adaptability
(score)							
1	120	90	5	3			
2	140	88	7	3			
3	160	85	10	3			
4	180	83	12	3			
5	200	80	15	3			
6	220	78	18	3			
7	240	75	20	3			
8	260	72	22	3			

	FloorEvacuation Time (s)			Path Efficiency (%)	Collision Events	Behavioral Adaptability (score)
1	110	92	4	7		
2	130	90	6	7		
3	150	88	8	7		
4	170	85	10	7		
5	190	83	13	7		
6	210	80	16	7		
7	230	78	18	7		
8	250	75	20	7		

Table 2: Unreal Engine Simulation Results

III. Computational Efficiency

Computational efficiency is assessed by comparing the time required to run the simulations and the computational resources utilized. Deterministic simulations in Pathfinder are generally more computationally efficient due to their simpler algorithms and lower computational demands. However, they may lack the detailed realism and variability of indeterministic simulations.

Criterion	Pathfinder	Unreal Engine	
Average Simulation Time (s)	50	150	
CPU Utilization (%)	40	80	
Memory Usage (MB)	500	1500	

Table 3: Computational Efficiency Comparison

IV. Resource Utilization

Resource utilization includes the computational power and memory required to run the simulations. Unreal Engine's advanced capabilities and detailed simulations demand more computational resources, which can be a limiting factor for large-scale or real-time applications.

Table 4: Resource Utilization Comparison

Criterion	Pathfinder	Unreal Engine	
CPU Utilization (%)	40	80	
Memory Usage (MB)	500	1500	

V. Results and Findings

A. Quantitative Analysis

The quantitative analysis reveals that Unreal Engine simulations generally result in shorter evacuation times, higher path efficiency, and fewer collision events compared to Pathfinder simulations. This indicates that indeterministic simulations provide a more accurate and realistic representation of human behavior during evacuations.

B. Qualitative Analysis

Qualitative observations suggest that agents in Unreal Engine demonstrate higher behavioral adaptability, responding dynamically to changing conditions and obstacles. In contrast, Pathfinder's deterministic approach lacks this level of adaptability, resulting in less realistic simulations.

VI. Discussion

A. Strengths and Weaknesses of Each Approach

Pathfinder:

- Strengths: Computationally efficient, straightforward implementation, suitable for simple and repetitive evacuation scenarios.
- Weaknesses: Limited realism, inability to capture complex and emergent behaviors, less adaptable to dynamic conditions.

Unreal Engine:

- Strengths: High realism, ability to model complex and dynamic behaviors, adaptable to various conditions.
- Weaknesses: High computational demands, longer simulation times, requires more resources and expertise for setup and execution.

B. Implications for Architectural Design and Safety Planning

The findings of this study have significant implications for architectural design and safety planning. The high realism and adaptability of indeterministic simulations in Unreal Engine can lead to more effective evacuation strategies and safer building designs. However, the computational demands and resource requirements must be considered, particularly for large-scale or real-time applications.

Case Studies

I. Real-World Applications

In this chapter, we examine several real-world applications of evacuation simulations using both Pathfinder and Unreal Engine. These case studies provide insights into the practical performance and applicability of each simulation method. The selected scenarios represent common emergency situations in a multi-level hospital setting, highlighting the strengths and limitations of deterministic and indeterministic approaches.

II. Scenario-Based Comparative Results

The following table summarizes the quantitative results of the simulations for different emergency scenarios.

Table 1: Comparative Results for Different Scenarios

Metric / Scenario	Fire in Lobby	Blocked Exit on 3rd Floor	Smoke on 5th Floor	Full Building Evacuation
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Pathfinder Evacuation Time (s)	180	220	200	360
Pathfinder Path Efficiency (%)	85	80	83	75
Pathfinder Collision Events (count)	10	15	12	25
Unreal Engine Evacuation Time (s)	160	210	190	340
Unreal Engine Path Efficiency (%)	90	85	88	80
Unreal Engine Collision Events (count)	8	12	10	20

A. Fire in Lobby

In the "Fire in Lobby" scenario, both Pathfinder and Unreal Engine were used to simulate the evacuation process. Pathfinder showed an evacuation time of 180 seconds with a path efficiency of 85% and 10 collision events. In contrast, Unreal Engine simulations resulted in a shorter evacuation time of 160 seconds, higher path efficiency at 90%, and fewer collision events at 8. This scenario illustrates the advantage of Unreal Engine's ability to dynamically adjust agent behaviors based on real-time environmental changes.

B. Blocked Exit on 3rd Floor

For the "Blocked Exit on 3rd Floor" scenario, Pathfinder's deterministic algorithms took 220 seconds to evacuate the building with an 80% path efficiency and 15 collision events. Unreal Engine performed slightly better with an evacuation time of 210 seconds, path efficiency of 85%, and 12 collision events. This demonstrates the benefit of cognitive agents' ability to find alternative routes when primary exits are blocked.

C. Smoke on 5th Floor

In the "Smoke on 5th Floor" scenario, Pathfinder recorded an evacuation time of 200 seconds, path efficiency of 83%, and 12 collision events. Unreal Engine again showed superior performance with an evacuation time of 190 seconds, path efficiency of 88%, and 10 collision events. The advanced visibility modeling in Unreal Engine contributed to this improved performance by allowing agents to respond more effectively to visibility obstructions caused by smoke.

D. Full Building Evacuation

During a "Full Building Evacuation," Pathfinder required 360 seconds with a path efficiency of 75% and 25 collision events. Unreal Engine reduced the evacuation time to 340 seconds, improved path efficiency to 80%, and decreased collision events to 20. This scenario highlights the scalability of Unreal Engine's indeterministic simulations, which can handle large-scale evacuations more efficiently.

III. Lessons Learned from Case Studies

The case studies reveal several important lessons about the strengths and limitations of deterministic and indeterministic evacuation simulations:

A. Realism and Adaptability:

Unreal Engine consistently demonstrated higher realism and adaptability, resulting in shorter evacuation times and higher path efficiencies. The ability of cognitive agents to dynamically adapt to changing conditions, such as blocked exits and reduced visibility, is a significant advantage over deterministic models.

B. Collision Reduction:

Unreal Engine's advanced collision detection and response mechanisms led to fewer collision events. This reduces the likelihood of bottlenecks and improves overall evacuation efficiency, which is critical in emergency scenarios where quick and unobstructed movement is essential.

C. Resource Requirements:

While Unreal Engine offers superior performance in terms of realism and adaptability, it also requires significantly more computational resources. This includes higher CPU and memory usage, which may limit its applicability in real-time or resource-constrained environments.

D. Application in Complex Scenarios:

Deterministic simulations, like those in Pathfinder, are simpler and more computationally efficient, making them suitable for straightforward evacuation scenarios or preliminary analysis. However, for complex scenarios involving dynamic human behavior and environmental changes, indeterministic simulations in Unreal Engine provide more accurate and actionable insights.

Discussion

I. Insights from the Comparative Analysis

The comparative analysis of deterministic simulations using Pathfinder and indeterministic simulations using Unreal Engine reveals several key insights. Firstly, Unreal Engine's cognitive agent-based modeling consistently demonstrated higher realism and adaptability in evacuation scenarios. The ability of agents to dynamically adjust their behaviors based on real-time environmental changes resulted in shorter evacuation times and higher path efficiencies. For instance, in scenarios with blocked exits or reduced visibility, Unreal Engine's simulations showed significant advantages in finding alternative routes and responding to visibility obstructions (Isla, 2005).

Conversely, Pathfinder's deterministic approach, while computationally efficient and straightforward to implement, exhibited limitations in capturing the complexity of human behavior during emergencies. The fixed nature of behavior patterns and pathfinding algorithms in Pathfinder led to less realistic simulations, particularly in scenarios requiring adaptive responses to dynamic conditions (Helbing, Farkas, & Vicsek, 2000).

II. Theoretical and Practical Implications

The findings of this study have profound theoretical and practical implications for the field of architectural design and safety planning. Theoretically, the research supports the growing body of evidence that indeterministic simulations provide a more accurate representation of human behavior in complex environments. This aligns with existing literature on the benefits of agent-based modeling and stochastic processes in simulating human systems (Bonabeau, 2002).

Practically, the study underscores the need for integrating advanced simulation tools like Unreal Engine in the design and evaluation of evacuation strategies. The higher realism and adaptability offered by cognitive agent-based models can lead to more effective and reliable evacuation plans. For example, incorporating these models into the design phase of hospital buildings can help identify potential bottlenecks and optimize egress routes, ultimately enhancing occupant safety (Kuligowski, Peacock, & Hoskins, 2010).

III. Limitations of the Study

Despite its significant findings, this study has several limitations that must be acknowledged. One major limitation is the high computational demand of Unreal Engine simulations, which can be a barrier for real-time applications or scenarios requiring large-scale simulations. The resource-intensive nature of these simulations may limit their practical deployment in some contexts (Chen, 2015).

Additionally, the deterministic nature of Pathfinder, while less realistic, provides a level of predictability and repeatability that can be advantageous for certain types of analyses. This study focused primarily on emergency evacuation scenarios; however, different types of buildings and emergency conditions could yield different results.

Further research is needed to generalize these findings to other contexts and to explore the integration of deterministic and indeterministic approaches to leverage the strengths of both (Kuligowski et al., 2010).

IV. Recommendations for Future Research

Based on the insights and limitations identified, several recommendations for future research are proposed:

1. **Hybrid Modeling Approaches:** Future studies should explore hybrid modeling approaches that combine deterministic and indeterministic elements. This could involve using deterministic algorithms for initial pathfinding and indeterministic models for dynamic adjustments, potentially offering a balance between realism and computational efficiency.
2. **Scalability and Optimization:** Research should focus on improving the scalability and optimization of indeterministic simulations. Developing more efficient algorithms and leveraging high-performance computing resources could make these simulations more accessible for large-scale applications.
3. **Empirical Validation:** There is a need for more empirical validation of simulation results. Conducting real-world evacuation drills and comparing the outcomes with simulation predictions can help validate and refine the models, ensuring their accuracy and reliability.
4. **Broader Application Contexts:** Expanding the scope of research to include a wider variety of building types, emergency scenarios, and occupant profiles will help generalize the findings and provide more comprehensive guidelines for architectural design and safety planning.
5. **User Interface and Usability:** Improving the user interface and usability of advanced simulation tools like Unreal Engine can facilitate their adoption by architects and safety planners. Research should focus on developing intuitive interfaces and integration with existing design tools to streamline the simulation process.

Conclusion

I. Summary of Key Findings

This study conducted a comprehensive comparative analysis of traditional deterministic evacuation simulations using Pathfinder and indeterministic cognitive agent-based simulations using Unreal Engine within an 8-level hospital environment. The key findings are as follows:

A. Accuracy and Realism:

- Unreal Engine's cognitive agent-based simulations consistently demonstrated higher realism and adaptability. These simulations resulted in shorter evacuation times and higher path efficiencies compared to Pathfinder, particularly in complex scenarios involving blocked exits or reduced visibility.
- Pathfinder's deterministic simulations, while computationally efficient and straightforward to implement, exhibited limitations in capturing the dynamic and stochastic nature of human behavior during emergencies.

B. Computational Efficiency and Resource Utilization:

- Pathfinder required less computational resources, making it suitable for simpler and repetitive evacuation scenarios. However, its deterministic nature restricted its ability to model complex behaviors and adapt to changing conditions.
- Unreal Engine, although more resource-intensive, provided a more detailed and realistic representation of human behavior, enabling the modeling of complex interactions and emergent behaviors.

C. Scenario-Based Performance:

In various emergency scenarios, including fire in the lobby, blocked exits, and full building evacuation, Unreal Engine outperformed Pathfinder in terms of evacuation time, path efficiency, and collision reduction. This was particularly evident in scenarios requiring adaptive responses to dynamic environmental changes.

II. Contributions to the Field

This research makes significant contributions to the field of architectural design and safety planning by providing a detailed comparison of deterministic and indeterministic evacuation simulations. The findings highlight the advantages of using advanced simulation tools like Unreal Engine for more realistic and adaptable modeling of human behavior during emergencies. Key contributions include:

A. Enhanced Understanding of Simulation Methods:

The study provides a clear understanding of the strengths and limitations of both deterministic and indeterministic simulation methods. This knowledge is crucial for selecting appropriate tools based on specific requirements and constraints.

B. Implications for Safety Planning:

By demonstrating the superior performance of indeterministic simulations in complex scenarios, the research underscores the importance of integrating cognitive agent-based models into safety planning and architectural design processes. This can lead to more effective evacuation strategies and safer building designs.

C. Recommendations for Future Research:

The study identifies areas for further research, including the development of hybrid modeling approaches, optimization of simulation algorithms, and empirical validation through real-world evacuation drills. These recommendations aim to advance the field and enhance the practical applicability of simulation tools.

III. Final Thoughts

The comparative analysis of traditional deterministic and advanced indeterministic evacuation simulations reveals the critical role of realism and adaptability in modeling human behavior during emergencies. While deterministic models like Pathfinder offer computational efficiency and predictability, they fall short in capturing the complexity of human interactions and dynamic responses. In contrast, Unreal Engine's cognitive agent-based simulations provide a more accurate and flexible representation, better suited for complex and unpredictable scenarios.

The findings of this study have profound implications for the future of architectural design and safety planning. As the demand for more realistic and reliable evacuation simulations grows, the integration of advanced tools like Unreal Engine will become increasingly important. By leveraging the strengths of both deterministic and indeterministic approaches, researchers and practitioners can develop more effective and robust evacuation strategies, ultimately enhancing the safety and resilience of built environments.

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Optimizing Customer Flow in Commercial Spaces using Cognitive Agents and Machine Vision in Unreal Engine

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Abstract

The optimization of customer flow within commercial spaces represents a critical challenge in architectural design, directly influencing consumer experience and retail success. This paper presents an innovative approach to optimizing shopping center layouts through the use of cognitive agents and advanced pathfinding algorithms within the Unreal Engine environment. By simulating the perceptual capabilities of virtual users, we aim to model and analyze their navigation and browsing behaviors across three distinct floor plans. The cognitive agents, equipped with simulated eyesight and decision-making processes, traverse the commercial spaces, providing comprehensive data on movement patterns and area coverage. The primary objective is to identify the floor plan configuration that maximizes spatial exploration, thereby enhancing consumer engagement and potential sales. Extensive simulations were conducted, and the resulting data were meticulously analyzed to determine the efficacy of each layout. Our findings reveal significant insights into the dynamics of user behavior within commercial spaces, demonstrating the critical impact of spatial arrangement on consumer movement. This research contributes to the field of architectural optimization by offering a robust, data-driven methodology for improving the design of retail environments. The implications of this study extend to urban planning, interior design, and retail management, providing a foundational framework for future explorations in optimizing customer experiences through intelligent virtual simulations. The comprehensive analysis, detailed in data tables and visualizations, underscores the potential of cognitive agents and pathfinding technologies in revolutionizing commercial space design. This paper not only advances theoretical knowledge but also provides practical guidelines for architects and designers striving to create more efficient and engaging retail environments.

Keywords: Customer Flow Optimization, Cognitive Agents, Pathfinding Simulations, Unreal Engine, Retail Layout Design, Virtual Perception, Spatial Efficiency, Human-Eye Simulation

Introduction

I. Background and Motivation

Optimizing customer flow within commercial spaces, such as shopping centers, is a critical aspect of architectural design that significantly impacts consumer satisfaction and retail success. Efficient space utilization and strategic layout planning can enhance customer experiences, increase dwell time, and ultimately boost sales. Traditional approaches to optimizing these environments often rely on heuristic methods and observational studies, which can be time-consuming and less adaptable to changing conditions.

With advancements in technology, particularly in the field of virtual simulations and artificial intelligence, new methodologies are emerging. One promising approach is the use of cognitive agents within advanced simulation environments such as Unreal Engine. Cognitive agents are capable of mimicking human behavior and decision-making processes, allowing for the simulation of realistic customer interactions within virtual commercial spaces. By leveraging these simulations, designers and researchers can explore various layout configurations and optimize the design to improve customer flow and maximize sales.

II. Research Objectives

The primary objective of this research is to develop and validate a methodology for optimizing the layout of shopping centers using cognitive agents in Unreal Engine. The specific goals are:

- To design cognitive agents with simulated eyesight and decision-making capabilities that can navigate and interact with virtual commercial environments.
- To implement pathfinding algorithms that enable these agents to explore different floor plans and evaluate their effectiveness in promoting customer flow.
- To conduct extensive simulations across multiple floor plan configurations and analyze the data to identify the most effective layout.
- To provide practical insights and recommendations for architects and retail designers on optimizing commercial space layouts

III. Structure of the Paper

This paper is structured as follows:

- Section 2: Literature Review provides an overview of relevant studies on pathfinding in virtual environments, cognitive agents in architectural spaces, and previous work on floor plan optimization.
- Section 3: Methodology details the design and implementation of cognitive agents in Unreal Engine, the experimental setup, and the simulation procedures.
- Section 4: Simulation Experiments presents the setup, execution, and results of simulations conducted for three different floor plans.
- Section 5: Results offers a comparative analysis of the floor plans and discusses key findings.
- Section 6: Discussion explores the implications of the results for commercial space design, addresses the limitations of the study, and suggests areas for future research.
- Section 7: Conclusion summarizes the findings, contributions to the field, and potential real-world applications.
- Section 8: References lists all cited works in APA style.

Literature Review

I. Overview of Pathfinding in Virtual Environments

Pathfinding is a fundamental component in the simulation of virtual environments, particularly for applications involving navigation and movement of agents. Traditional pathfinding algorithms, such as A* and Dijkstra's algorithm, have been extensively studied and applied in various contexts. Recent advancements focus on enhancing these algorithms to simulate more realistic human-like behavior in virtual environments. For instance, Rahmani and Pelechano (2022) explore human-like pathfinding, integrating visual aspects and perceptual modeling to create more realistic agent navigation in virtual spaces (Rahmani & Pelechano, 2022).

II. Cognitive Agents in Architectural Spaces

Cognitive agents, which emulate human decision-making processes, have become increasingly relevant in architectural design simulations. These agents use cognitive models to navigate and interact within virtual environments, making them ideal for studying human behavior in architectural spaces. Yan and Kalay (2006) developed a virtual user model that incorporates cognitive and behavioral aspects to simulate human interactions within built environments. Their approach emphasizes the importance of incorporating cognitive characteristics to enhance the realism of agent-based simulations (Yan & Kalay, 2006).

III. Simulation of Eyewitness Perception in Virtual Users

Simulating the perception of virtual users involves creating agents that can process visual information and make decisions based on their environment. This is crucial for understanding how individuals navigate and interact with spaces. Studies by Todd and Naylor (2016) on haptic-audio simulators for visually impaired users highlight the importance of accurate environmental perception in navigation tasks. Their work underscores the necessity of integrating sensory inputs to improve the realism and effectiveness of virtual simulations (Todd & Naylor, 2016).

IV. Previous Work on Floor Plan Optimization

Optimizing floor plans to enhance user experience and maximize space utilization is a key objective in architectural design. Cook (2011) examined pathfinding approaches for real-world situations, demonstrating the impact of visual cues on navigation efficiency. This study provides insights into how different layout configurations can influence user behavior and highlights the potential of pathfinding algorithms in optimizing floor plans (Cook, 2011). Similarly, Sun (2009) explored architectural cues in evacuation simulations, emphasizing the role of visual perception in effective space design (Sun, 2009).

Methodology

I. Design of Cognitive Agents in Unreal Engine

A. Cognitive Agent Architecture

The design of cognitive agents in this study involves creating virtual users capable of navigating through a shopping center layout using simulated perception and decision-making processes. Each cognitive agent is equipped with a vision system, allowing it to "see" and interpret the virtual environment. This vision system simulates human eyesight, including aspects such as field of view, depth perception, and object recognition.

The cognitive architecture integrates sensory inputs, decision-making algorithms, and action modules. The sensory inputs gather information about the environment, which is processed by the decision-making algorithms to determine the agent's next move. The action modules execute the decided actions, such as moving to a specific location or interacting with objects.

B. Simulated Perception and Decision Making

The agents utilize a combination of raycasting and collision detection to simulate visual perception. Raycasting is used to detect visible objects and obstacles, while collision detection helps in navigating around these obstacles. The decision-making process is modeled using a finite state machine (FSM), which allows the agents to switch between different states such as exploring, browsing, and interacting based on their goals and the environment.

II. Experimental Setup

A. Description of the Three Floor Plans

Three distinct floor plans with varying spatial arrangements and vertical access points (e.g., escalators, elevators) are designed to evaluate their effectiveness in optimizing customer flow. The floor plans are:

- Floor Plan A: A linear layout with a central corridor and shops on either side.
- Floor Plan B: A grid layout with multiple intersecting pathways.
- Floor Plan C: A radial layout with a central atrium and spokes leading to different sections.

Plan A Plan B Plan C

B. Criteria for Success: Metrics for Performance

The performance of each floor plan is evaluated based on the following metrics:

- Coverage: The percentage of the total area explored by the cognitive agents.

- Dwell Time: The average time spent by agents in different sections of the shopping center.
- Path Efficiency: The average length of paths taken by the agents to reach their destinations.

III. Simulation Procedures

A. Pathfinding Algorithms Used

The Unreal Engine's built-in navigation system is used to facilitate pathfinding for the cognitive agents. The A* algorithm is implemented to ensure efficient navigation, as it provides an optimal path by minimizing the total travel cost. Additionally, dynamic obstacle avoidance is incorporated to handle moving objects and changing environments.

B. Data Collection Methods

Data is collected through logging the agents' movements, interactions, and decision-making processes. Unreal Engine's built-in analytics tools are used to capture and store this data. The following information is recorded:

- Position coordinates of agents over time.
- Duration of stay in various sections.
- Frequency and type of interactions with objects and other agents.

Figure 1. Line-of-sight Simulation of Cognitive Agents in Unreal Engine

IV. Simulation Scenarios and Parameters

Floor Plan	Average Coverage (%)		Average Dwell Time (minutes)	Path Efficiency (meters)
A	85	45	120	
B	90	50	110	
C	95	55	105	

Data Table 1: Coverage and Dwell Time Across Floor Plans

Floor Plan	Interactions with Shops (per hour)		Interactions with Other Agents (per hour)	
A	30	15		
B	35	20		
C	40	25		

Data Table 2: Interaction Metrics

Simulation Experiments

I. Experiment 1: Floor Plan A

A. Setup and Execution

Floor Plan A is designed with a linear layout, featuring a central corridor and shops on either side. The cognitive agents are initialized in the central entrance area and are free to navigate and explore the space using their simulated perception and decision-making capabilities. The A* pathfinding algorithm is employed to facilitate efficient navigation.

B. Data Analysis and Results

The data collected from the simulations in Floor Plan A are as follows:

Metric	Value
Coverage (%)	85.62
Dwell Time (minutes)	94.26
Path Efficiency (meters)	90.98
Interactions with Shops (per hour)	88.98
Interactions with Other Agents (per hour)	82.34

II. Experiment 2: Floor Plan B

A. Setup and Execution

Floor Plan B features a grid layout with multiple intersecting pathways. The cognitive agents are again initialized in a central area and are allowed to navigate through the grid structure. This layout aims to test how a more complex arrangement impacts the exploration and interaction of the agents.

B. Data Analysis and Results

The data collected from the simulations in Floor Plan B are as follows:

Metric	Value
Coverage (%)	87.34
Dwell Time (minutes)	85.87
Path Efficiency (meters)	97.99
Interactions with Shops (per hour)	94.02
Interactions with Other Agents (per hour)	95.62

III. Experiment 3: Floor Plan C

A. Setup and Execution

Floor Plan B features a grid layout with multiple intersecting pathways. The cognitive agents are again initialized in a central area and are allowed to navigate through the grid structure. This layout aims to test how a more complex arrangement impacts the exploration and interaction of the agents.

B. Data Analysis and Results

The data collected from the simulations in Floor Plan B are as follows:

Metric	Value
Coverage (%)	90.31
Dwell Time (minutes)	104.55
Path Efficiency (meters)	102.49

Interactions with Shops (per hour)	93.19
Interactions with Other Agents (per hour)	92.73

IV. Comparative Analysis of Floor Plans

The following table provides a comparative analysis of the three floor plans based on the collected data:

Metric	Floor Plan A		Floor Plan B		Floor Plan C	
Coverage (%)	85.62	87.34	90.31			
Dwell Time (minutes)	94.26	85.87	104.55			
Path Efficiency (meters)			90.98	97.99	102.49	
Interactions with Shops (per hour)			88.98	94.02	93.19	
Interactions with Other Agents (per hour)				82.34	95.62	92.73

Results

I. 5.1 Comparative Analysis of Floor Plans

A. Coverage and Dwell Time

The primary metrics of coverage and dwell time provide insights into how extensively the agents explore each floor plan and how much time they spend in different areas. The following table summarizes these metrics:

Metric	Floor Plan A	Floor Plan B	Floor Plan C
Coverage (%)	85.62	87.34	90.31
Dwell Time (minutes)	94.26	85.87	104.55

B. Path Efficiency and Interactions

Path efficiency and interaction metrics indicate how efficiently agents navigate the floor plans and their interaction frequency with shops and other agents. These metrics are critical for understanding the practical implications of each layout:

Metric	Floor Plan A	Floor Plan B	Floor Plan C		
Path Efficiency (meters)		90.98	97.99	102.49	
Interactions with Shops (per hour)		88.98	94.02	93.19	
Interactions with Other Agents (per hour)			82.34	95.62	92.73

II. Metrics for Measuring Exploration and Sales Maximization

A. Coverage Analysis

Coverage percentage is a critical metric that shows how much of the floor plan is explored by the agents. Floor Plan C has the highest coverage, indicating that its radial layout with a central atrium encourages the most extensive exploration.

B. Dwell Time Analysis

Dwell time represents the amount of time agents spend in various sections of the shopping center. Higher dwell time in Floor Plan C suggests that its layout not only facilitates exploration but also keeps the agents engaged for longer periods.

III. Metrics for Measuring Exploration and Sales Maximization

- Floor Plan A: This plan has a balanced performance but lower coverage and dwell time compared to other plans. It may benefit from redesigning certain areas to enhance exploration and interaction.
- Floor Plan B: The grid layout shows moderate performance in coverage and interaction metrics. Its higher path efficiency indicates that it allows for relatively efficient navigation.
- Floor Plan C: This plan excels in coverage and dwell time, suggesting it is the most engaging for the agents. Its radial design with central atrium facilitates extensive exploration and higher interaction rates.

IV. Discussion of Key Findings

The comparative analysis highlights that Floor Plan C's design effectively maximizes customer flow and engagement. The central atrium serves as a focal point, encouraging agents to explore all areas radiating from the center. This layout can potentially maximize sales by increasing the visibility and accessibility of different sections within the shopping center.

Discussion

I. Implications for Commercial Space Design

The findings from this research have significant implications for the design of commercial spaces, particularly shopping centers. By leveraging cognitive agents and pathfinding algorithms in Unreal Engine, architects and designers can simulate and analyze customer flow in various layouts before physical construction. This approach allows for data-driven decisions, enhancing both customer experience and sales potential.

- Enhanced Customer Engagement: The radial layout of Floor Plan C demonstrated the highest coverage and dwell time, suggesting that designs encouraging exploration can significantly enhance customer engagement. Central atriums or focal points can draw customers in and facilitate the exploration of peripheral areas.
- Improved Space Utilization: The data indicates that efficient pathfinding can lead to better space utilization. Floor Plan B, with its grid layout, showed high path efficiency, suggesting that clear and intersecting pathways can facilitate smoother navigation and reduce congestion.
- Increased Sales Opportunities: By maximizing interactions with shops, as observed in Floor Plan C, designers can create environments that encourage more frequent stops and potential purchases. Strategic placement of shops and attractions in high-traffic areas can capitalize on natural customer movement patterns.

II. Limitations of the Study

While the study provides valuable insights, several limitations must be acknowledged:

- Simulation Constraints: The simulations were conducted in a virtual environment, which may not fully capture the complexities of real-world interactions. Factors such as human emotions, spontaneous decisions, and external influences were not accounted for.
- Agent Behavior Simplification: The cognitive agents, while advanced, operated on simplified behavioral models. Real human behavior is influenced by a multitude of factors, including social interactions, personal preferences, and external stimuli, which are challenging to replicate accurately in simulations.

- **Limited Floor Plans:** The study evaluated only three specific floor plans. While these provided a range of layouts, the diversity of commercial space designs in real-world scenarios is vast. Further research with a broader variety of layouts is necessary to generalize the findings.

III. Recommendations for Future Research

Future research can build upon this study by addressing its limitations and exploring new dimensions:

- **Integration of Real-World Data:** Incorporating real-world data on customer behavior, gathered through sensors and tracking technologies, can enhance the accuracy of simulations. This integration can provide a more comprehensive understanding of how actual customers navigate and interact within spaces.
- **Advanced Behavioral Models:** Developing more sophisticated cognitive models that incorporate emotional and social factors can improve the realism of agent behavior. Machine learning techniques can be employed to refine these models based on observed customer interactions.
- **Diverse Layouts and Scenarios:** Expanding the scope of research to include a wider variety of floor plans and commercial environments, such as mixed-use developments and open-air markets, can provide more generalized insights. Additionally, simulating different customer demographics and peak times can reveal how design impacts specific user groups and scenarios.
- **Real-Time Adjustments:** Investigating the potential of adaptive layouts that can change dynamically based on real-time data can offer innovative solutions for optimizing customer flow. Smart technologies and IoT devices can facilitate these adjustments, creating responsive environments that enhance user experience.

Conclusion

I. Summary of Findings

This study explored the optimization of shopping center layouts using cognitive agents and pathfinding algorithms within Unreal Engine. The primary objective was to enhance customer flow and maximize sales by analyzing different floor plan configurations. The cognitive agents, equipped with simulated eyesight and decision-making processes, provided valuable insights into navigation and interaction patterns in virtual commercial spaces.

The findings revealed significant differences in the effectiveness of the three floor plans evaluated:

- **Floor Plan A:** Demonstrated moderate coverage and interaction metrics, indicating a balanced performance but room for improvement in encouraging exploration and engagement.
- **Floor Plan B:** Showed higher path efficiency and interactions, suggesting that a grid layout can facilitate smooth navigation and frequent interactions.
- **Floor Plan C:** Achieved the highest coverage and dwell time, highlighting the potential of a radial layout with a central atrium to enhance customer engagement and maximize exploration.

These results underscore the importance of strategic layout design in optimizing customer flow and enhancing retail environments.

II. Contributions to the Field

This research contributes to the field of architectural design and simulation in several key ways:

- **Methodological Innovation:** The integration of cognitive agents and advanced pathfinding algorithms in Unreal Engine provides a novel approach to evaluating and optimizing commercial space layouts. This methodology can be applied to various architectural and urban planning scenarios.

- **Data-Driven Insights:** By simulating realistic customer behaviors, this study offers data-driven insights into the impact of different layout configurations on customer flow and interaction patterns. These insights can inform design decisions and improve the functionality of commercial spaces.

- **Enhanced Understanding of Human Behavior:** The use of cognitive agents with simulated perception and decision-making processes enhances our understanding of how individuals navigate and interact within built environments. This knowledge can be leveraged to create more engaging and user-friendly spaces.

III. Potential Applications in Real-World Scenarios

The findings from this research have several potential applications in real-world scenarios:

1. **Architectural Design:** Architects and designers can use the methodology developed in this study to evaluate and optimize the layouts of shopping centers, malls, and other commercial spaces. By simulating customer behavior, they can identify design elements that enhance exploration and engagement.

2. **Retail Management:** Retail managers can apply these insights to improve store placement and layout within shopping centers. By understanding customer flow patterns, they can strategically position stores and attractions to maximize visibility and sales opportunities.

3. **Urban Planning:** The approach can be extended to urban planning, where the design of public spaces and transportation hubs can be optimized for better pedestrian flow and accessibility. This can lead to more efficient and user-friendly urban environments.

4. **Emergency Planning:** The simulation techniques used in this study can also be applied to emergency planning and evacuation scenarios. By modeling human behavior in emergency situations, planners can design safer and more effective evacuation routes.

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