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Studying the effect of modern construction technologies on time, cost, and quality of Iran mass housing projects

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ABSTRACT

The daily-incremental population of Iran and the incremental need for housing as well as the insufficient traditional construction systems of Iran have increased the tendency to use modern technologies in mass housing projects. It is tried in this research to study the effects of using modern construction technologies on time, cost, and quality of Iran mass housing projects, their problems, and ways to develop. The results of this research show that these technologies in Iran will accelerate project time up to 50% than the traditional technics. Moreover, construction costs reduced to 30% in projects with fewer housing units than the traditional technics, and costs reduced in projects with many units in total per capita. The maximum use of this technology in Iran is in the step of structure-basis and facility installation. In recent years, the entrepreneurs' tendency has increased toward modern technologies. Based on findings, providing the appraisal motives from some institutions such as municipality will increase public interest to use these technologies in the state. Based on the decision-making matrix of multi-criteria decision-making method, the maximum effect of modern technologies on Iran mass-housing projects have higher integrity and solidity of structure, better quality, the longer life-time of structure, acceleration in construction time, better resistance against earthquake, lower target costs in mass scale, beauty and lower harmful effects on the environment, better efficiency of the installation, and optimization of building energy consumption.

Keywords: **Modern technologies, Construction, Time, Cost, Quality, Mass housing projects.**

1. INTRODUCTION

The approach of using modern technologies in mass housing projects seems necessary by the occurrence of events such as the earthquake in Iran and the inefficiency of elementary and conventional systems of construction projects. The construction technologies in Iran can be generally classified as elementary construction, traditional construction, and new construction systems. The new construction system has been started in Iran since the history of construction to now and is still used in some countries and rural areas. In this technic, the bearing parts are made of clay and mud, wood and mud, rock and mud, or brick and clay. In addition, their cover is made of clay arch, wooden beam, or plant fibers. Some of the used human force in these buildings is skillful or half-skillful, and the accessible traditional materials are used. Construction by these technics has the minimum resistance against natural disasters (earthquakes, floods, storms, etc.), and can only be used as a temporary shelter. The construction operations in the traditional construction system were done by the experts, half-skillful, and navvy people. Buildings with brick-bearing walls were included in this classification. Some expert authorities using this system include navvy, masonry, plasterer, painter, blacksmith, plumber, electrician, insulation worker, tile-worker, asphalt-worker, glass-glazier, etc. This construction technic is used now in most rural and some urban areas of Iran or the margin of metropolises. The most skillful master masonries, delicate-touch workers, and traditional carpenters are found among these makers. Based on Iran regulations, the maximum permitted floor is 4, and the permitted height is 12 m. The new construction system,

also called improved or developed construction technics to include operation by the mentioned experts in the previous technic who use mechanical building installations and types of machinery to increase the work speed and volume. Buildings with metal or concrete structures are in this classification. Some of the used installations in these types of constructions include types of fixed and removable cranes, electric hoists, metal scaffolding, concrete making machines (fixed and removable), cement and color sprayers, welding machines, etc. Building operation speed in this technic is averagely 20-48 h/m2 infrastructure. It means building operation speed can relatively increase using the mechanical and electric installation. The number of floors and the total height of the building can't be predicted by more than 50 floors and 150 m, respectively, for using concrete and metal structure. The initial investment to use this technic is significant about the volume of building operation, purchase, or rent of equipment. Operation stops for working or financial problems that are the disadvantages of this technic and make waste for the project. Now, most constructions in urban areas and mass housing projects use this technic. In addition, teaching workers and experts in related fields, the invention of new tools and equipment, and the use of modern technologies have made these buildings built in a shorter time with lower cost and more safety. One of the main reasons to use modern technologies in mass housing projects is increasing construction speed and promotes quality. In many execution plans, the operations speed has a determining role in the selection of construction materials. Studying the existed traditional systems in Iran shows that most of these systems can't execute mass housing projects in a short time with proper quality, and one of the proper solutions that Iran government can make a balance in the housing market in Iran is using modern technologies in a mass housing project. One reason for not using these technologies is the lack of enough information about the effects of these technics, which are unfortunately observed in some entrepreneurs and engineers. In this research, the effects of using these technologies are studied on time, cost, and quality of mass housing projects, and some policies will be provided to develop and raise them. Most research about modern construction technologies in the world has been an applied study and unique for the specific condition of each state. The following research can be referred to about this field. Hong studied the economic and social conditions of China about modern technologies and the proper technics of industrialization in some cities of the state. Moreover, he provided some policies to develop the application of these technics based on the China condition [1]. Verweij et al. [2] evaluated the future of industrialization technics and their coordination with various human needs in addition to modern concrete construction technologies referring to the Netherlands by surveying. Russel et al. [3] studied the adaptation of modern construction technologies with the social and economic needs in Canada and stated the optimization manner of these technics based on the economic condition of Canada. Roger et al. [4] studied modern construction technologies from a quality, economical, and sustainable development conditions. In addition, they invested their development technics in industrial communities. Han et al. [5] studied the modern technologies for the construction of green structures and stated the green-housing obstruction steps. Moreover, they explained the advantages of green housing in this research. Kozlovska et al. [6] studied the modern construction technics using wooden materials and explained construction advantages of this technic, operation steps, and cost estimation manners. Zhanga et al. [7] studied the modern technics of building information modeling in new technologies and explained information modeling of building in 3d and their advantages. Furthermore, they offered some policies to improve energy consumption and reduced the outflow of building materials. Krarti et al. [8] evaluated the effect of these technics and modern technologies and the construction of the productivity of energy consumption in Bahrain housing buildings. They calculated energy loss by surveying the built construction projects by the new technologies and optimized these buildings by providing policies for energy consumption. Other studies have also explored the effects of new technologies on rapid and convenient implementation [9] and reduced weight of the buildings [10] as well as its application in the refurbishment of buildings [11] Along with the development of new technologies, there is a need to use new materials. In this regard, extensive research has investigated Hebelex concrete blocks [12] autoclaved aerated concrete and the need to observe their technical requirements [13] along with drawbacks such as cracks in walls made with these materials and related solutions [14]. Also, the use of knauf and its significant effect on reducing the weight of the building [15] and promoting its application [16], the use of foam concrete and additives [17] and the dependence of its resistance on density and other chemical properties [18] as well as the promising future of foam concrete are other research undertaken about these new materials [19] Also, there is extensive research on the use of fibers in concrete mix and its effect on mechanical properties [20], fire resistance [21], and explosion and impact of fibrous concrete [22]. The use of new technologies has been the subject of other research as well. Some research on mitigating the effects of safety and security threats [23] and passive defense have also discussed the application of new technologies [24]. In these studies, considering that the main goal of the passive defense is to secure and reduce the vulnerability of the public infrastructure [25], the first step to construct a solid structure against progressive failure is the selection of appropriate materials [26] so that passive defense can play its vital role in various dimensions [27] In this regard, nanotechnology can significantly contribute to the realization of this goal [28]. This technology, in addition to the provision of new materials [29] and improved resistance of new buildings to threats such as chemical corrosion induced by acid rain and other destructive and limiting factors [30], play an important role in the steel, concrete [31] and glass industries, which are the main materials used in construction projects [32]. The application of new technologies has spread to other fields of construction. The use of new technologies in the building energy [33], the troubleshooting of building systems [34], the cooling of concrete arched dams during construction [35], and improved performance of materials such as heat regulation in cement plaster [36] are some of the subjects addressed by researchers. The use of new technologies to increase the energy efficiency of buildings by considering climatic features [37], predicting building vibrations induced by the underground railway networks [38], forecasting costs with methods such as artificial intelligence [39], and improving the construction cost

estimation [40] have also been explored by researchers in recent years. The benefits of new technologies in all fields, especially construction, and their impact on construction costs, are of paramount importance as they can facilitate global problems. In this regard, the coronavirus outbreak, as a global issue, has prompted some researchers to investigate issues such as the construction cost of isolated prefabricated medical units for COVID-19 [41]. The results of such studies, combined with new technologies and their impact on reducing construction costs and time, can highlight the role of the construction industry in countering similar diseases in the future. In light of the above and the lack of concentrated research on the effects of new technologies in reducing cost and time, the present study investigates this issue in the context of mass buildings.

2. METHODOLOGY

Before starting, it should be mentioned that due to the lack of information, in this paper, a variety of methods have been adopted to investigate the issue in question are in-person interviews and consultation with experts in the field of construction and field surveys in mass production projects. Also, given that new construction technologies have varying effects on time, cost, and quality of mass construction projects, the analytic hierarchy process (AHP) model was used to investigate the effects of the above factors and their ranking. The characteristics are the main factors of using modern construction technologies in Iran are consisting of production focus, massive production, standardization, specialization, proper organization and management, and integrity. The whole construction chain must be mentioned to achieve modern construction technologies in all their aspects. In this chain, construction is the first ring of design, which itself is classified into 3 elements of "design, architecture, structure, and installation." Of course, it is obvious that urbanization design is the basis of all. In the traditional chain in Iran, it is observed by the transition from the design step to the output step that more than 300 building items have been usually included in designs. Of course, this number based on the scale and volume of the project may be different. These items include the skeleton, walls, ceiling, door, window, rock, installation, elaborated work, etc. This large number of items firstly poses a major problem in mass production and the use of new technologies and, secondly, in the overall efficiency of the manufacturing process. For example, in the traditional construction of Iran, large volumes of construction materials waste and rework occur in the process of construction for lack of component parts and lack of coordination between the designer, producer, and manufacturer. Therefore, the classification of building pieces in the logical and made ranges, the number of building activities are reduced by standardization of elements, and the number of building items reduces from 300 to 50. This reciprocal process requires proper coordination in project management. In this regard, it was tried in the current research to use various methods for lack of data, including in-person interview and gathering the experts' ideas about construction, surveying in mass housing projects, and preparing analytical hierarchy process (AHP). The proper method in this research is an in-person interview with Iran construction experts and mass housing execution groups. These people are the best ones to be used in this field for having efficient experience and specialization. It is tired in this part to study the mass housing projects and effective factors on them by gathering data from various references. In the field of statistics, decision-making technologies with multiple indexes have been in place for several years to evaluate the effects of various factors in which ranking or prioritization is concerned. Meanwhile, AHP has been used more than other technologies in management science. AHP has been used in management science more than the other technologies. AHP is used when the effect on several factors is important, and decision making is associated with several choices and criteria. The proposed criteria can be qualitative and quantitative. The basis of this model is decision-making based on paired comparisons. These comparisons show the effect of each factor along with the rival choices. Finally, AHP logic is in a way to combine the obtained matrixes from paired comparisons to indicate the effect of various factors quantitatively. According to the subject of this research about the effect of various factors on modern construction technologies in mass housing projects, this is a proper technic and has been used for this research. According to the number of projects and volume of the statistical population, several samples have been calculated using the Morgan table. The members of the statistical population include the involved experts and factors in this project, such as entrepreneurs, counselors, contractors, and beneficiaries of mass housing projects. Education level of this statistical population is shown in Figure 1 and experience level of them is shown in Figure 2 Their ideas were gathered by an in-person interview, call, or email. Population volume and sample volume were selected 70 and 59, respectively, based on the number of studied projects and use of the Morgan table.

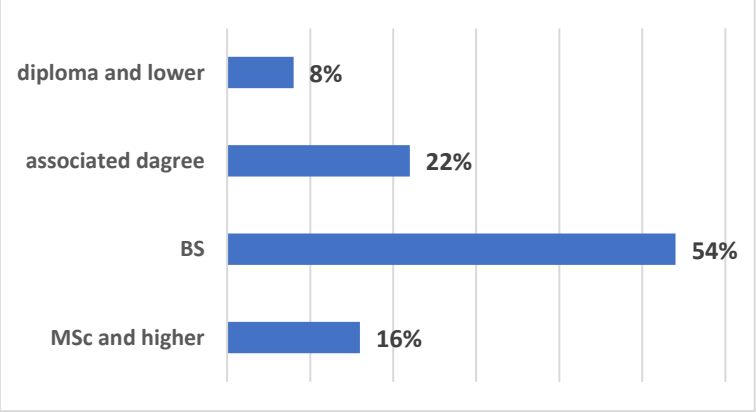

Figure 1. Education level of the statistical population of this research

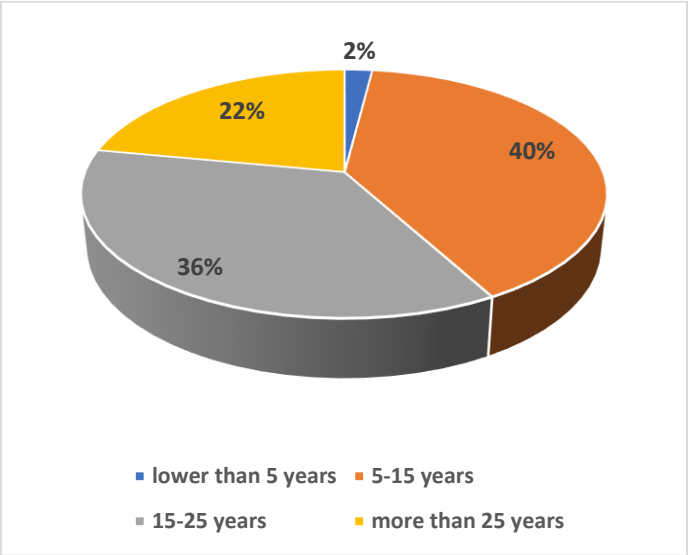

Figure 2. experience of the statistical population of this research

3. RESULTS AND DISCUSSION

The conclusions are examined in five areas, as follows:

a) The scope of using new technologies:

Considering the improved quality of mass construction projects in Iran over the last decade, most of the participants stated that new technologies were used in approximately 25 to 50% of the mass construction projects under their management.

b) The impact of new technologies on project time:

The new technologies curtail the time of projects by 50 to 75% compared to traditional and conventional technologies. The notable point is that none of the participants asserted that the use of these technologies led to a delay, which is one of the main advantages of new technologies in mass construction projects.

c) The impact of using new technologies on the cost of construction projects (less than 50 units):

In this regard, although the use of new technologies in construction projects with a large number of units can be cost-effective, the utilization of these technologies in building projects with less than 50 units can increase costs by approximately 30%.

d) Familiarity with and the desire of employers and supervisors as well as contractors' expertise to use new technologies

Employers of large mass construction projects are more fascinated with new technologies than employers of small projects, and many employers and supervising engineers are not well acquainted with new technologies. The level of skill and experience of contractors in using new technologies has improved in recent years with a subsequent improvement in the quality of projects.

e) Cooperation of organizations:

Aa for the level of cooperation and contribution of relevant organizations such as municipalities in improving the quality and development of new technologies, the results indicate a serious gap in this area. Accordingly, there are not sufficient incentives to promote the use of these technologies and the quality of the construction industry in the country.

In this section, the effect of modern construction technologies on some parameters, such as time and cost of mass housing projects are evaluated. It was indicated in surveying that modern construction technologies had been used mostly in 25-50% of Iran's mass housing projects. About 12% of the statistical population knows this figure between 75 to 100% of projects (Figure3). Moreover, studies have shown that the use of modern construction technologies in projects is mostly for more than 50-floor projects, and the popular and traditional technologies have been used in fewer floor buildings. Experts know higher costs of modern technologies than the traditional ones as the main reason.

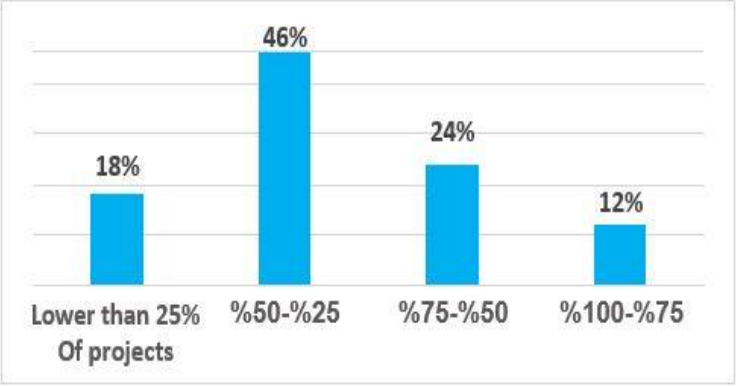

Figure 3. The extent of using modern construction technologies in Iran mass housing projects

Most experts of the statistical population state that the use of modern construction technologies accelerates the time of projects than the traditional and conventional ones, and that is about 50-70%. The important point in this question is that none of the statistical population members know these technologies as the delay reason for projects that is one of the important advantages of modern construction technologies in mass housing projects. One of the main disadvantages of the traditional technologies in Iran, particularly at the construction time of the skeleton, is that the legs and retaining jacks must remain under the roofs for a long time until the concrete can reach the required strength after molding and finishing each ceiling. Since most work teams in Iran has a limited number of legs and jacks, this matter is a disadvantage of the traditional technologies, while the problem of the essential time to make the frame and cast concrete is solved for a higher speed of modern than traditional technologies. It can be seen in Figure 4 about collective housing projects in Iran using modern tunnel molding technology.

Figure 4. The execution sample of mass housing projects in Iran using modern tunnel molding technology

Surveying in Iran shows that modern construction technologies usually increase the construction cost in mass housing projects with lower than 50-floor buildings. However, it accelerates the project time instead and particularly increases the quality, which may not be so much important for some entrepreneurs for the present housing conditions of Iran, and the economic aspects may be more important for them. It can be claimed based on the results of this research that in mass housing projects with more than 50-floor buildings using modern construction technologies is both relatively economical and will increase the quality and reduce project delay. In addition, installations of pipes and electrical installations will be conducted faster.

Figure 5. Images of Cobiax technology and the traditional technic of concrete joists and foam.

This part is about a case study of traditional technic and modern technology in mass housing projects. The case study of this part is related to roofing using the traditional technic of using concrete joists and foam and the modern technology of cobiax. The traditional technic of using concrete joists and foam is popular today in the country in most buildings, and most engineers and contractors are familiar with this technic. The conducted case study is related to the building in the 100-unit project. This building has 6 floors with a total foundation of 1200 m. figure 5 shows the execution of two technics. And Table 1 shows comparing the cost of cobiax technology with the traditional technic of concrete joists and foam

Table 1. Comparing the cost of cobiax technology with the traditional technic of concrete joists and foam

		For cobiax roofing			For concrete joists and foam roofing		
price	unit	value	Currency (Rial)	Total price (Rial)	value	Currency (Rial)	Total price (Rial)
Used concrete	m3/m2 of roof	0.45	1200000	540000	0.55	1200000	660000
Used rebar	Kg/m2 of roof	50	18000	900000	65.5	18000	1179000
Execution salary	m2 of roof	1	300000	300000	1	200000	200000
Design, construction and delivery of materials	m2 of roof	1	390000	390000	1	460000	460000
total				2130000			2499000

In this mode, the price difference of the mentioned building with 1200 m foundation is 442800000 Rials ((2499000 - 2130000) *1200). Moreover, each roofing (without calculating concrete drying time) for each roof by the traditional technic of concrete joists and foam is about 7 days and by cobiax modern technic is about 5 days. It will take 12 days less by calculating 6 roofs to execute. It is noticed that using the modern technic of cobiax can reduce the roofing execution time to 28% less and save 15% execution cost.

3.1. ENTREPRENEURS' TENDENCY TO THE MODERN TECHNOLOGIES

- Surveying results show that little percentage of entrepreneurs and owners interest in using modern construction technologies. In this regard, there are several important points, as follows:
- Entrepreneurs' interest in great mass housing projects with many units is more than in small projects with fewer units.
- Lack of interest of most entrepreneurs is the increased cost.
- Lack of efficient attention to the housing quality in Iran market is one reason for lack of interest.

Many entrepreneurs don't know the advantages of modern technologies.

Figure 6 shows two samples of modern construction technologies in Iran. In this regard, the dominance of the supervisor system on modern technologies also has a direct effect on the use and development of them. This issue is important in two aspects. First, the more the supervisor system has dominated these technologies, the better the quality of the operations will be done. Second, the entrepreneurs will be prevented from using the traditional technics, which relatively have lower quality.

Figure 6. The samples of modern construction technologies in Iran (right side is the modern building frames- left side is the heating and cooling modern technologies of building)

3.2. EXPERTISE AND EXPERIENCE OF THE CONTRACTORS OF MODERN BUILDING TECHNOLOGIES AND THEIR EFFECT OF PROJECTS QUALITY

Another issue with the direct effect on the quality of mass housing projects in Iran is the expertise and experience of working teams and contractors. The higher-level experience and expertise do contractors have in applying

modern construction technologies, the better quality and performance would happen for their structures and installations. In addition, defects, rework, and waste of materials will be prevented. Research results show that the expertise and experiences of work teams and contractors in applying modern technologies in Iran have been fortunately improved in the recent decade, and entrepreneurs are relatively satisfied with this condition. Some reasons for it are as follows:

Increasing the number of contractors and their ability to provide better services at a lower cost

- The improper performance of traditional and conventional technologies
- Increasing the level of building units buyers' expectations to buy units with efficient quality
- specialization of modern construction technologies

3.3. THE EFFECTS OF RELEVANT ORGANIZATION SUCH AS MUNICIPALITY

The discussion about the effects of the relevant organization such as municipality and engineering system organization are very important about the cost and quality of applying modern construction technologies in mass housing projects. These institutions should be as follows:

- First, most entrepreneurs should be acquainted with the advantages of these technologies by making culture, proper education, and actions. Therefore, the quality of the project will be improved.
- Second, a proper motive can be made to develop the application of these technologies in other mass housing projects, in addition, to reduce the direct costs of the project by encouraging actions such as granting or lowering the cost of permits for projects made with these technologies.

Figure 7 shows the opinion of the statistical community about the cooperation and coordination of relevant organizations such as municipalities for the development of modern technologies. As shown, the entire statistical community believes that the level of cooperation and coordination of organizations in this area is less than 75%.

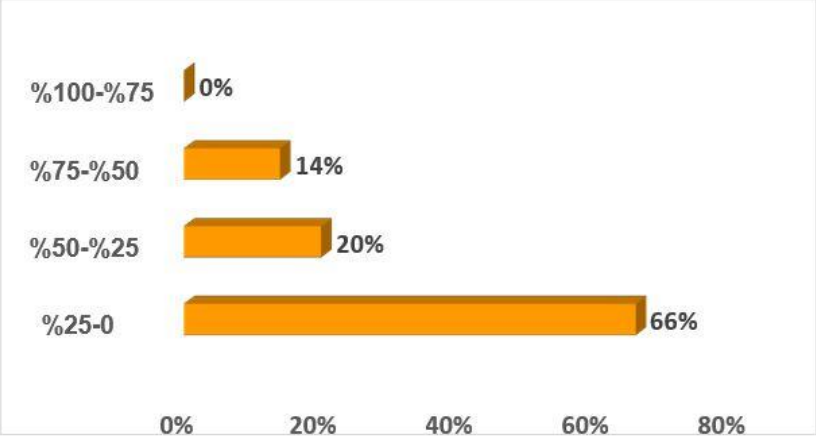

Figure 7. Cooperation and coordination of relevant organizations such as municipalities to develop the modern technologies.

Results show the serious weaknesses in this part. The reality is that no proper action has been conducted to make culture and train these technologies in Iran. Moreover, no proper motive has been made to apply the development of these technologies and qualify for the construction industry in Iran. For example, buildings that use the traditional and low-quality technologies should pay the same costs to get permission as modern and high-quality technologies, and no practical motive is provided to develop the application of these technologies.

3.4. THE EFFECTS OF MODERN TECHNOLOGIES

Since the effects of modern construction technologies are different on time, cost, and quality of various mass housing projects, the AHP model was used to examine the effects of the mentioned factors and their ranking. Therefore, the following matrix was prepared, and experts were asked to attribute a number from 1.9 to 9 to the mentioned choice based on the effect of each factor on the other factors. After removing the incomplete and distorted matrixes, the mean attributed scores to each factor are, as Table 2. This scoring method is used to determine the relative weight of various choices, to form the choices matrixes, and to study the effect of each factor. After the essential calculations and forming the relevant matrixes, the results will be as follows if the effects of modern technologies on Iran mass housing projects than others are compared and ranked.

1-More integrity and strength of structures with a relative weight of 0.3676 with the maximum effect.

2-Better quality and longer lifetime of structure with a relative weight of 0.2445 in the second rank, with the maximum effect.

3-Accelerating the time of the structure construction with a relative weight of 0.1636.

4-More strength against the natural risks, and events such as earthquake with a relative weight of 0.0947.
5-Reduction of the target costs with a relative weight of 0.0458.
6-Beauty and lower harmful effects on the environment with the relative weight of 0.0608
7-Better efficiency of installation and optimization of energy consumption with a relative weight of 0.0227.

In this mode, the compatibility index or CI is 0.63 that is acceptable and shows the compatibility and integrity of the given answers by experts.

Table 2. Prioritization of the effects of modern construction technologies using AHP model

	More integrity and strength	Better strength against natural disasters such as earthquake	Accelerating the structure construction time	Better quality in longer lifetime and utilization of structure	Reducing target costs	Better efficiency of installation and optimization of energy consumption	Beauty and fewer harmful effects on the environment
More integrity and strength	1	5	3	2	7	9	6
Better strength against natural disasters such as earthquake	1.5	1	1.2	1.4	2	5	3
Accelerating the structure construction time	1.3	2	1	1.2	5	6	4
Better quality in longer lifetime and utilization of structure	1.2	4	2	1	4	8	5
Reducing target costs	1.7	1.2	1.5	1.4	1	3	1.2
Better efficiency of installation and optimizing energy consumption	1.9	1.5	1.8	1.6	1.3	1	1.5
Beauty and fewer harmful effects on the environment	1.6	1.3	1.4	1.5	2	5	1

4. CONCLUSION

According to the procedure of mass housing projects improvement in Iran in the recent decade, most statistical population stated that about 25-50% of mass housing projects had used the modern technologies under their responsibility. Furthermore, the time of projects reduces than the time of the traditional and conventional projects, and this amount is about 50-75% time of the traditional technologies. It is important to note that none of the statistical population knows the use of these technologies as a delay factor, and this matter is one of the important advantages of modern technologies in building mass housing projects. Most experts believe about the effect of modern technologies on the cost of projects that modern technologies have increased costs by about 30% in projects with fewer than 50 units. The entrepreneurs' tendency to use modern technologies in mass housing projects is more than small projects with fewer units. Moreover, many entrepreneurs and supervising engineers don't have enough information about modern technologies. The expertise and experience of contractors to use modern technologies and the quality of projects have improved in recent years, fortunately. The obtained results from cooperation and coordination of the responsible organizations such as municipalities to improve the quality and develop the modern technologies showed the serious weakness, and proper motives haven't been provided to apply the development of these technologies and quality the building industry in Iran.

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AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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