JHE
Journal of Hydrosciences and Environment

The Best Suitable Newly Introduced Construction Management Technologies for Temporary Settlement Sites after Disasters From Sustainable Development Perspective

A. Seirafi[1], H. Kamalan[2,*]

1. MSc Student, Department of Civil Engineering, Pardis Branch, Islamic Azad University, Pardis, Iran.
2,.. Associate Professor, Department of Civil Engineering, Pardis Branch, Islamic Azad University (Corresponding author).*

ARTICLEINFO

Article history:

Received: 13 April 2020
Accepted: 20 June 2020

Keywords:
Construction Management Technologies,
Settlement sites,
Environmental Conditions,
AHP,

ABSTRACT

The provisioning of a minimum standard level of settlement and the designing of camps are among the primary and essential rights and requirements of those subjected to disasters or conflicts. The presence of shelters is essential to resist diseases and protect against natural and non-natural hazards. It is also important to maintain the dignity of humans in the family and social frameworks in tough situations. The present study involved the emergency tent of the UN high commissioner for refugees (UNHCR), Q-shelter, tarpaulin-concrete shelters, recycled-paper pipes, rock-block buildings, safe units, pre-construction wooden building system, lightweight steel frame (LSF) building system, insulating concrete formwork (ICF) building system, and sliding structure system. This study investigates the possibility of using new construction management methods and technologies in Iran to establish temporary settlement sites after disasters from different perspectives, such as consistency with environmental conditions, passive defense, cost, execution speed, ease of facilities, construction technologies, and execution quality via the hierarchical analysis approach. According to the final scores of new temporary settlement establishment methods, Q-shelters were found to be the most consistent method with environmental conditions. Also, the highest passive defense score was obtained for the LSF building system. Also, the final weights of the decision criteria indicated that the highest effect was derived for execution speed at a coefficient of 0.203. Finally, obtaining a score of 0.156, the LSF building system was found as the best building system in the mass housing project based on the six criteria, followed by the sliding structure building system in the second rank. Moreover, the smallest score was obtained for the rock block system.

1. Introduction

Natural disasters and war are the most important factors threatening human life, causing the loss of numerous lives, destroying installations, equipment, and buildings, and imposing irreparable economic and social costs. As human gathering centers, cities have been most subjected to such damages (Gohari, 2013).

The present study attempts to identify new methods for establishing temporary settlement sites and their effects on such sites after disasters while observing passive defense principles (Davis, 1985). It also seeks to understand how such methods can be used and developed in Iran, considering the conditions of Iran. Furthermore, it seems to be necessary to investigate the energy consumption and environmental pollutant generation of each operational plan (Motlagh et al., 2005). Moreover, the material utilizing for each method is highly important in terms of energy saving (Babaee et al., 2011)

Kermani et al. (2015) studied the use of new paper structures in establishing temporary shelters in disaster management. They introduced paper structures and investigated how they could be used as safe shelters after an earthquake in light of their high transportation and installation speed.

Hasangholipour et al. (2015) investigated the minimum standards and per capita required for the settlement of survivors after incidents. They attempted to propose a proper model for designers and crisis managers. The required per capita of a predefined site in District 3 of Urmia, Iran, based on the standards of the Sphere Project and other available studies and standards.

Fallahi et al. (2006) analyzed temporary settlements in Turkey. After providing a brief introduction to the coordinates of the 1999 Izmir Earthquake and determining the damages, provided the damages imposed on the city of Adapazari, Turkey. Then, a general description of measures taken by international groups and the Turkish government in the Izmir Region, Turkey was provided.

* Corresponding author's email: kamalan@pardisiau.ac.ir

DOR: 20.1001.1.23455608.2020.4.7.2.1

Gholian et al. (2014) evaluated different post-disaster settlement systems and their history in the world. They introduced the advantages and disadvantages of each system with the help of experts through an analytical-descriptive approach. The systems were compared for the geographical position of Iran to identify the best system for execution and transformation into a residence system.

Mostaghni et al. (2014) proposed a post-earthquake building reconstruction management plan. Investigating the situation of Kharv, Iran, before and after an earthquake, suggestions were rendered on proper reconstruction, including the establishment of a space for temporary settlement that was assigned to people periodically and would be delivered to other cases after the completion of the reconstruction.

Salahi et al. (2015) investigated the effect of creating temporary settlement sites on the impact reduction of natural incidents and disasters. Investigating the structure of Tabriz, Iran, they attempted to identify criteria for establishing temporary settlement sites as safe places for affected individuals. The proposed sites had the required infrastructural, cultural, social, safety, and disciplinary conditions for the settlement of individuals so the temporary settlement sites could be easily evacuated and used for other purposes after the completion of reconstruction.

Mozaffari et al. (2014) studied the effects of using pre-constructed technologies after incidents on time, cost, and quality in Shiraz, Iran. They introduced and reviewed the applications of pre-constructed and industrial technologies. Then, interviews and questionnaires with the relevant authorities were employed to collect data. The data were analyzed by Spearman’s correlation, measuring the effects of employers, contractors, and equipment on time, cost, and quality. The results suggested that the execution speed of pre-constructed structures is higher than that of in-situ structures. It was suggested that the execution of permanent pre-constructed buildings with the observation of some aspects is more economic than in-situ structures. It was also found that the pre-construction technology and building industrialization improve the quality and safety of structures.

Haddad et al. (2014) investigated the Indigenous housing of Rudbar, Iran, by modeling a new anti-earthquake technology. They aimed to design houses by new earthquake-resistant methods and observing the native principles of the region. The results indicated that a post-incident house design should involve earthquake resistance and native design principles.

Maham et al. (2015) studied the effect of employing the geographical information system (GSI) technology on post-earthquake crisis management. New methods were proposed using software analyses on the layers and maps of damaged regions to rapidly identify suitable and safe locations for temporary settlement and find the shortest relief paths. Also, the use of GIS to manage the rescue operation and remove debris from the destroyed locations was described.

Koppel et al. (2017) evaluated the construction systems of industrial wood products, including thermally modified wood (i.e., thermowood), to enhance the market share. It was suggested that recent advancements in wood products and their use in the pre-production process required the construction management process that needed to be standardized and integrated. The identified criteria and theoretical foundations used for the creation of general system construction management were provided.

Generalova et al. (2016) investigated a modular building using recycled paper-pipes. They considered temporary methods for the use of modular units in construction. The advanced global experience of modular building construction was analyzed. It was emphasized that modular construction could lead to reduced project design and engineering time, decreased cost, and improved construction productivity.

Kozlovska et al. (2015) proposed a cost approximation approach for modern construction methods, including the lightweight steel frame (LSF), thermowood systems, and 3D panel. They focused on the technical analysis of modern wood-based construction systems. Moreover, their proposed method estimated cost. The budget index (BI) was estimated based on a case study of a wooden building system represented by ten wooden houses in different shapes and sizes.

Iran experiences many natural and non-natural disasters every year. This suggests the particular importance of the temporary settlement of affected individuals. Factors such as environmental consistency passive defense, time, quality, and performance have essential effects on the establishment of temporary settlement sites. The establishment should not take a long time so relief services could be rendered to affected individuals in a short time. (Fallahi , 2006)

2. Materials and Methods

In the science of decision-making or the study of the effects of different factors in which a solution is selected from available alternatives or the factors are prioritized, decision-making methods, or multiple indexes, have appeared in recent years. The analytical hierarchy process (AHP) has been employed more commonly in management. Proposed in the 1970s, the AHP is among the most popular multi-purpose decision-making techniques. It reflects the natural human behavior and thinking. It investigates complicated problems based on their mutual effects, makes them simple, and solves them. (OCHA, 1995)

The AHP can be used when decision-making encounters several decision alternatives or criteria. The criteria can be either quantitative or qualitative. This decision-making technique is based on pairwise comparisons. The decision-maker begins the decision process by building a hierarchical decision tree. The hierarchical decision tree represents comparison factors and alternatives and then performs a set of pairwise comparisons. The comparisons indicate the weights of the factors for the alternatives. Finally, the logic of the AHP combines the pairwise comparison matrixes to obtain the optimal decision.

The present study evaluates new settlement construction methods by the views of a committee of experts, consulters, and contractors to finalize the alternatives and then prioritize, score, and compare them. The committee included nine experts. Table 1 provides the details of the committee.

Table 1. The details of the experts

Position	Number	Degree	Experience (year)
Consulter	2	Master of Civil Engineering	15-20
Contractor	3	Bachelor of Civil Engineering	8-23
Academics	1	Ph.D. of Civil Engineering	15
Red Crescent Expert	3	Bachelor	15

As can be seen, contractors and consulters accounted for a significant portion of the committee to perfectly recognize the study's subject. It should be noted that the experts confirmed the sufficiency and distribution levels. According to the data obtained from the questionnaires, the variables of the model in Expert Choice v.1 were included as input data, obtaining the final decision-making matrix for the five criteria, including the construction cost index, execution speed index, environmental condition consistency index, ease of construction equipment and technology index, and execution quality. The matrix consisted of the mean responses of the respondents.

Using a researcher-made questionnaire, the effects of new construction management methods and technologies on different factors of settlement sites were evaluated based on environmental and passive defense principles to "investigate the experience of settlement sites in Iran in terms of performance and service after disasters."

The questionnaire was delivered to the committee of experts. Then, they were asked to respond to the questions in the first part of the questionnaire based on their experience and expertise and then examine the effects of new methods on different factors of such sites based on the conditions of Iran.

Considering that different factors are important and influential in terms of sustainable development in the construction and use of settlement sites after a disaster (Comerio, 1998) and that new methods have different effects on different factors, it is required to prioritize the factors based on the effects. The AHP methods are employed to prioritize the effects of different factors. The factors included:

- The locating and design of settlement sites,
- Proper construction and use of initial infrastructures, such as water and power,
- The access routes of the sites,
- Water resources and food,
- Health and wastewater disposal,
- Internal security of the sites,
- Public spaces and structures
- Communication infrastructure, such as telephones,
- The vulnerability of the sites to adversary attacks in situations such as war, and
- The vulnerability of the sites to disasters such as floods and earthquakes.

3. Results

According to library studies, a long list of new construction management methods technologies in Iran to establish settlement sites and decision-making factors was developed. The alternatives included

1- The emergency tent of the UN high commissioner for refugees (UNHCR),
2- Q-shelter,
3- Tarpaulin-concrete shelters,
4- Recycled paper pipes,
5- Rock block buildings,
6- Safe units,
7- LSF building system,
8- Pre-construction wooden building system,
9- Insulating concrete formwork (ICF) building system, and
10- Sliding structure system

Additionally, the decision-making criteria involved
1- Passive defense,
2- Construction cost index,
3- Execution speed index,
4- Environmental consistency index,
5- Ease of construction equipment and technologies, and
6- Execution quality index.

A questionnaire was developed to investigate the priorities and weights of the criteria and alternatives for pair-wise comparison, as shown in Table 2.

A similar pair questionnaire involving the entire alternatives was developed and responded to for the pair-wise comparison and prioritization of the alternatives.

Based on the criteria and responses, the data were fed to Expert Choice, investigating the inconsistency rate, as shown in Table 3. According to Table 3, the entire inconsistency rates were obtained to be smaller than 10%, suggesting that the results were reliable.

The total inconsistency rate was calculated to be 0.03. Also, the new settlement site establishment methods were prioritized based on environmental consistency, as shown in Fig. 4.

Table 2. The sample questionnaire of comparing and prioritizing the indexes

Index i	Priority																	Index j
Construction cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Execution speed
Construction cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Environmental consistency
Construction cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Ease of construction equipment and technologies
Execution speed	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Environmental consistency
Execution speed	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Ease of construction equipment and technologies
Environmental consistency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Ease of construction equipment and technologies

Table 3. Inconsistency Rates

Questionnaire Number	**Inconsistency Rate**	**Questionnaire Number**	**Inconsistency Rate**
1	0.04	20	0.04
2	0.03	21	0.04
3	0.05	22	0.04
4	0.05	23	0.05
5	0.02	24	0.02
6	0.08	25	0.03
7	0.04	26	0.04
8	0.05	27	0.05
9	0.02	28	0.05
10	0.08	29	0.05
11	0.05	30	0.05
12	0.04	31	0.04
13	0.02	32	0.07
14	0.03	33	0.03
15	0.03	34	0.03
16	0.04	35	0.05
17	0.07	36	0.04
18	0.05		
19	0.06		

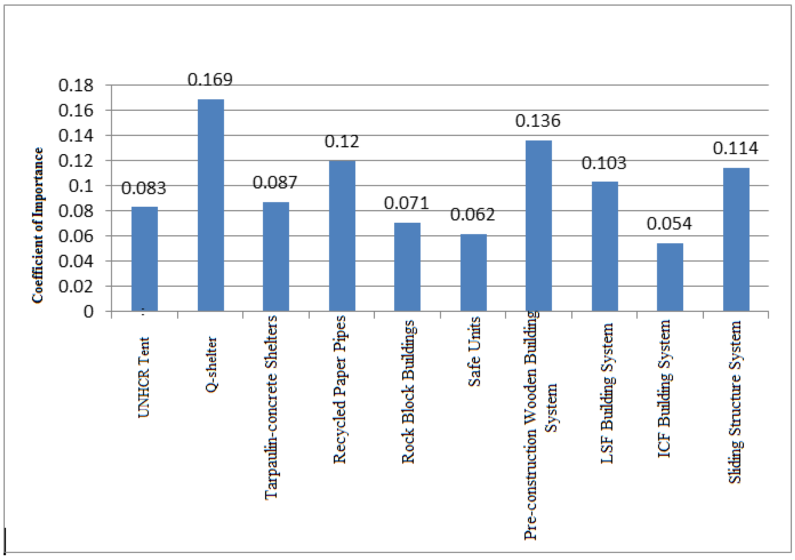

Fig. 1. The environmental consistency scores of the alternatives

As can be seen, the Q-shelter obtained the highest score of 0.169 as the most environmentally consistent alternative, while the ICF building system obtained the lowest score as the least environmentally consistent alternative. Fig. 2 compares the indexes and alternatives.

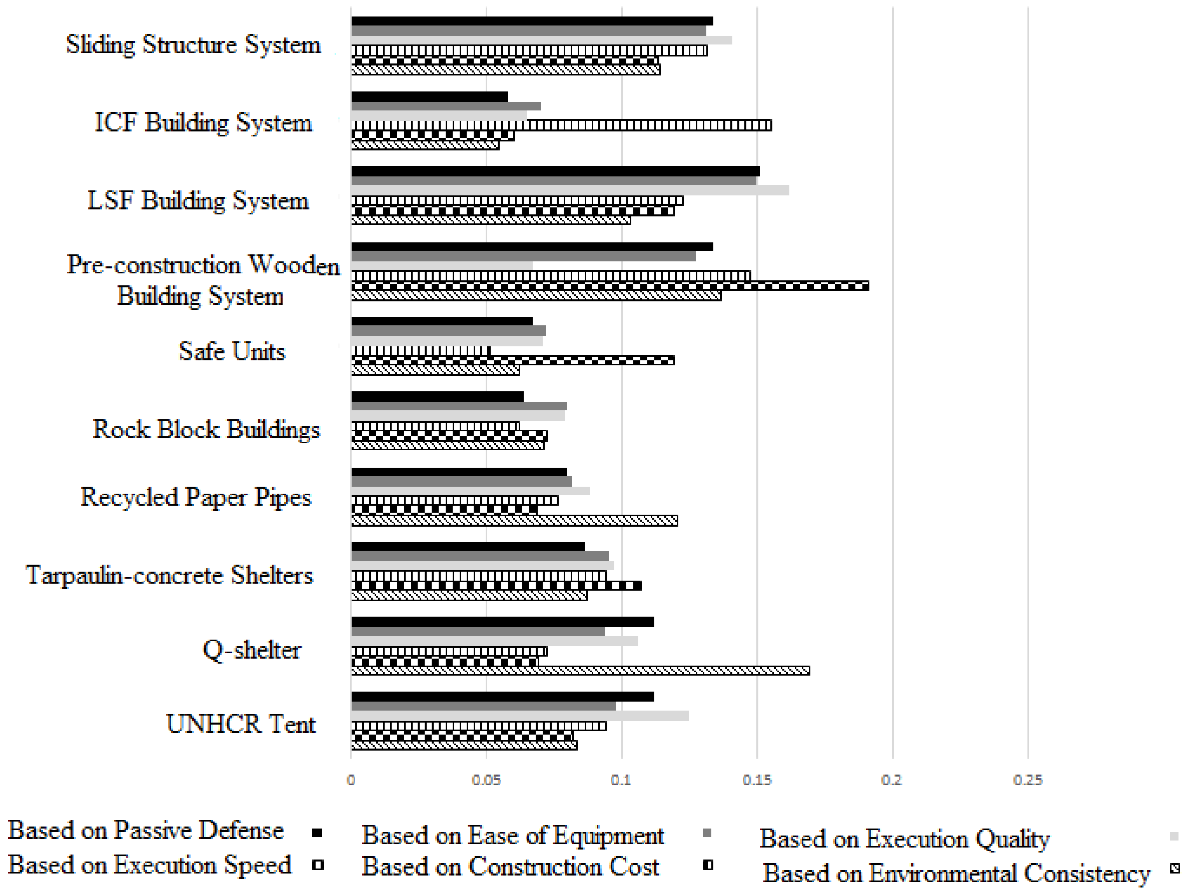

Fig. 2. The comparison of the indexes and alternatives

To identify the highest system based on the entire criteria, it is required to build the pairwise comparison matrix of the criteria. Fig. 3 shows the weights of the influential criteria. As can be seen, the execution speed obtained the highest score of 0.203.

Finally, by performing the AHP and applying the coefficients of the influential criteria, the new settlement establishment methods were prioritized, as shown in Fig. 4. As can be seen, the LSF building system, shown as M7, obtained the highest score. Fig. 5 compares the priority scores of the new settlement establishment methods. As can be seen, the LSF building system obtained the highest score of 0.156.

Obtaining a score of 0.156, the LSF building system ranked first in the mass housing project based on six criteria, including construction cost, execution speed, environmental consistency, ease of construction equipment and technologies, passive defense, and execution quality. The sliding structure system ranked second. Also, the rock block building obtained the smallest score. Table 6 prioritizes the new settlement establishment methods based on their scores.

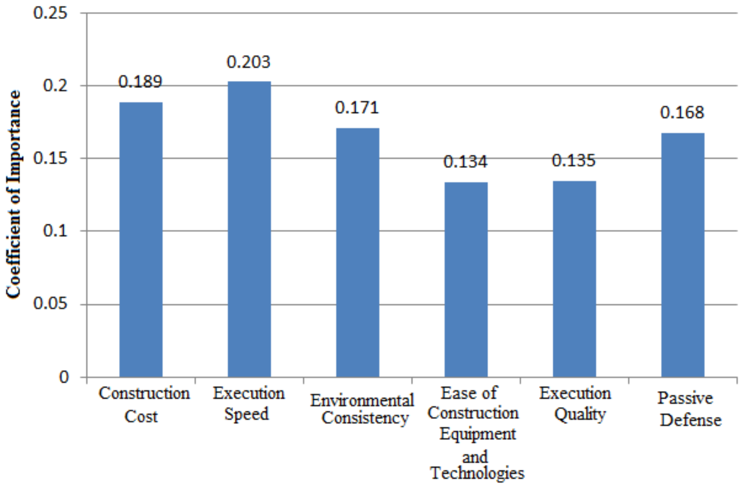

Fig. 3. The final weights of the decision

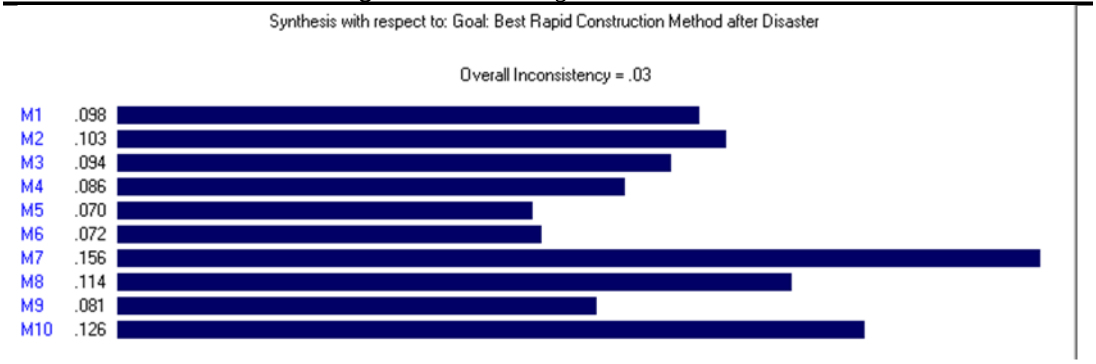

Fig. 4. The prioritization of the new settlement establishment methods

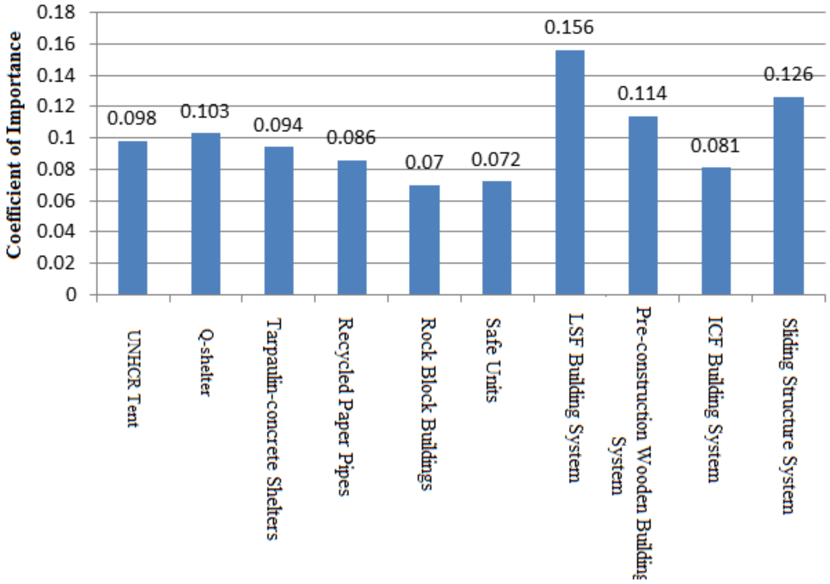

Fig. 5. The comparison of the priority scores of the new settlement establishment methods

Table 4. The prioritization of the new settlement establishment methods based on their scores

New Building System	Score
LSF building system	0.156
Sliding structure system	0.126
Pre-construction wooden building system	0.114
Q-shelter	0.103
Tarpaulin-concrete shelters	0.094
UNHCR tent	0.098
Recycled paper pipes	0.086
ICF building system	0.081
Safe units	0.072
Rock block buildings	0.070

Finally, according to the AHP prioritization results, the settlement methods were prioritized in the order of 1) LSF building system, 2) pre-construction wooden building system, 3) Sliding structure system, 4) Q-shelter, 5) tarpaulin-concrete shelters, 6) UNHCR tent, 7) recycled paper pipes, 8) ICF building system, 9) safe units, and 10) rock block buildings. The LSF system is of high importance in light of its particular features; it offers many more advantages over other industrialization systems, including

1) The structural components are pre-constructed. Pre-construction improves the construction quality, reduces the workshop execution cost, and increases productivity, which is of high importance in industrialization, while other traditional industrial structures do not offer such an important feature.
2) The construction operation is either completely dry or consumes a small amount of water during the construction procedure. This is essential in arid climates such as Iran. Unlike the suggestions of non-responsible individuals that Iran has a capacity for a population of 150 million, the climate of Iran cannot provide water to more than 40 million people. Also, the building industry is among the most water-consuming industries. Thus, the LSF system serves as the only proper alternative.
3) The environmentally pollutant materials such as cement is reduced to 10%. Cement is one of the most pollutant industries In Iran. Since it increases the generation of carbon gases, creates greenhouse conditions in the production path, imposes highly alkaline media, lacks a capability of complete recycling, and makes residential spaces prone to diseases such as rheumatoid arthritis, cement is an essential enemy of the environment.
4) It provides structural advantages, such as a light weight, which offers easy production and execution. The reduced weight reduces the effects of earthquake acceleration on the structure, protecting the buildings and residents. Also, indeterminate structures allow for repair and replacement even when a part of the structure is damaged. These features add one more advantage to the structure; the enhanced number of floors based on the load-bearing capacity by a minimum and a maximum number of 1 and 3, respectively. However, other industrialization systems lack this advantage.
5) The entire components and materials can be recycled and reused, either directly or indirectly, in a transformed or non-transformed manner. Also, they do not impose material waste. Other industrial structures do not offer this important advantage.
6) It can be properly combined with other conventional structures in the form of roots and walls to offer its advantages. For example, the distributed loads of a bearing LSF wall and a non-bearing LSF wall are below 180 kg and 120 kg. The dead load reduces structural sections and weights, provides security, stability, and economical benefits, and improves the construction speed. Almost no other walls can offer such important advantages.
7) It provides particular features in urban planning and urban management, including the lack of considerably dangerous destructive impacts during incidents such as earthquakes due to an integrated material system, provision of a light weight, the indetermination of structures, the lack of urban pollution during building operation due to dry conditions, the pre-construction of structural materials and components, and the lack of noise pollution due to light building operation.

4. Conclusion

The present study attempted to identify the most effective settlement method in Iran after disasters since Iran is prone to natural and non-natural disasters. A questionnaire was developed to collect data. The data were analyzed by Expert Choice. Six indexes were included, namely environmental consistency, passive defense, execution speed, execution quality, execution cost, and ease of access to construction equipment and technologies. The following results were obtained:

1) According to the final results of new settlement methods based on environmental consistency, the highest scores were obtained to be 0.169 and 0.136 for Q-shelters and pre-construction wooden structures, respectively. Also, the lowest score was obtained to be 0.054 for the ICF system.
2) The analysis of the results based on passive defense indicated that the highest and lowest scores were derived to be 0.151 and 0.058 for the LSF and ICF systems, respectively.
3) According to the construction cost results, the largest score was calculated to be 0.191 for the pre-construction wooden system, while the smallest score was derived to be 0.06 for the ICF system.
4) According to the final execution speed results of the new settlement technologies, the largest and smallest scores were obtained for the ICF system and safe units, respectively.
5) According to the results of the new settlement methods based on the ease of construction equipment and technologies, the highest score was obtained to be 0.15

for the LSF system, while the lowest score was derived to be 0.07 for the ICF system.

6) The final execution quality results of the new settlement methods revealed that the greatest score was obtained to be 0.162 for the LSF system, while the smallest technical score was calculated to be 0.065 for the ICF system.
7) The final weights of the decision-making criteria revealed the most influential criterion to be the execution speed with a coefficient of 0.203.
8) Based on the construction cost, execution speed, environmental consistency, easy of construction equipment and technologies, execution quality, and passive defense, the highest building systems in the mass housing project system were found to be the LSF and sliding structure systems with the scores of 0.156 and 0.126, respectively. Also, the lowest score was obtained to be 0.07 for the rock block system.

6. References

1. Babaee, S., Sabour, MR., Kamalan, H. 2011, “Simulation of Natural Gas Saving through Foam Lightweight Concrete Utilization in Residential Buildings”, Iranian Journal of Environmental Health Science and Engineering, 8(4): 337-346.
2. Comerio, M C. 1998. Disaster Hits Homes: New Policy for Urban House Recovery, University of California Press, USA.
3. Corsellis, T. and Vitale, A. 2015. Transitional Settlement: Displaced Populations. Cambridge: University of Cambridge.
4. Davis, I. 1985. Shelter after Disaster. PHD dissertation, University College London, Development Institute, London.
5. Fallahi, A. 2006. The Need to Plan a Comprehensive Plan for the Design of Camps and Emergency Accommodation in Unforeseen Events. Iran: Shahid Beheshti University.
6. Fallahi, A., Kari Jafari, B. and Omidvar, B. 2006. “Temporary Settlement in Turkey,” Iran: University of Medical Sciences, Zanjan.
7. Generalova, M., and Kuznetsova, A. 2016. “Modular Buildings in Modern Construction,” Journal of Theoretical Foundation of Civil Engineering, 3: 167-172.
8. Gohari, h. and Gholamali, H. 2013. “Passive Defense Planning and Locating Urban Shelters Using Fuzzy Logic, Case study of Kerman Urban Area one”, Quarterly Journal of Geography and Environmental Studies, 2:7-13.
9. Gholian, S., Borhani, B. and Jamei, A. 2014, “Evaluation of Various Building Systems for Temporary Settlement Sites After Disasters.” Journal of Crisis Management, 2:5-10.
10. Hadad, S., and Rahmani, M. 2014. “Indigenous Housing in Rudbar, with Modeling of Modern anti-Earthquake Technology,” Iran: University of Yazd.
11. Hasangholi Pour, S., Sharif Nejad, J. and Abdol Hoseini, J. 2015. “Minimum Standards and per Capita Accommodation Required for Survivors after Disaster,” Iran: Shahid Beheshti University of Hamedan.
12. Kermani, A. and Kashizadeh, A. 2015. “Application of newly Introduced Paper Structures in creating Temporary Shelter in Crisis Management,”Journal of Architectural, Urban Planning and Urban Management Research, 2:1-10
13. Koppel, T. 2017. “Evaluating the Risks in the Construction Wood Product System through a Criticality Assessment Framework,” Journal of Asian Architecture and Building Engineering, 11: 387–395.
14. Kozlovská, M., and Spisáková, M. 2015. “Modern Methods of Construction vs. Construction Waste,” Journal of Ecology and Environmental Protection, 3:483-490.
15. Maham, A., Jafarizadeh, M. and Ghahramani, M. 2015. “Use of GIS Technology in Crisis Management after an Earthquake,” Journal of Comprehensive Crisis Management, 1:5-9.
16. Mileti, D. 1999. Disasters by Design: A Reassessment of Natural Hazards in the United State. Washington D.C: University of Colorado of Boulder.
17. Mostaghni, P. and Nourozi, A. 2014. “Post-Earthquake Housing Reconstruction Management Plan,” Journal of Structure, Architecture and Urban Development ,3: 1-14.
18. Motlagh, MSP., Farsiabi, MM., and Kamalan HR. 2005. “An Interactive Environmental Economy Model for Energy Cycle in Iran,” Journal of Environmental Health Science & Engineering, 2: 41-56.
19. Mozafari, Kh., Fallah, A., and Faezi, F. 2014. “Investigating the effect of using Prefabricated Technologies after Disaster on Time, Cost and Quality” , Iran: Islamic Azad University, Meybod Branch, Yazd.
20. OCHA. 1995. “The Use of Military and Defense Assists in Relief Operation”. United Nations Office for The Coordination of Humanitarian Affairs.

Salahi, A., Roshanai, A., and Roshanai, T. 2015. “Investigate the role of Temporary Accommodation in Reducing the Effects of Natural Disasters,” Journal of Structure, Architecture and Urban Development, 2:5-8.