IMPLEMENTING AHP APPROACH TO SELECT A PROPER METHOD TO BUILD HIGH-RISE BUILDING (CASE STUDY: TEHRAN)

Amir Hesam Zamani Kia
Faculty of Civil Engineering, School of Construction Management and Engineering
Islamic Azad University
Shoushtar, Khouzestan, Iran
E-mail: amirhesamzk@yahoo.com

Mehdi Mahdavi Adeli
Faculty of Civil Engineering, School of Construction Management and Engineering
Islamic Azad University
Shoushtar, Khouzestan, Iran
E-mail: mehmahad@yahoo.com

ABSTRACT

Tehran is one of the most densely populated cities in the world and one of the most important problems of it is the lack of suitable land for the building, so there is a strong need to build high-rise buildings. High-rise buildings desperately need to improve the integration, planning and control of construction quality, etc. This has leaded to the creation of innovative and modern techniques in the high-rise building industry that each of these methods has its own advantages and disadvantages, but despite the pressing need, a comprehensive research has not yet done on the appropriate way for high-rise buildings in Tehran. It is tried in this research, given the effective criteria on high-rise building, to select the best option, considering the methods that there is the building possibility in the current situation. In this paper, at first 15 most important effective criteria for decision making to select proper method of high-rise building in Tehran was identified through questionnaire. Then AHP methodology and Expert Choice software was used to choose the best industrial method for high-rise building in Tehran. In this survey the most appropriate method for high-rise building in Tehran was identified in the condition of applying all the identified criteria that they are respectively: tunnel formwork, concrete buildings (traditional), steel bolt and nut, steel buildings with welded joints, Reinforced concrete structures with continuous frame.

Keywords: AHP, high-rise buildings, Tehran.

1. Introduction

Construction industry has a key role in wealth production of any country and development of its social, economic and construction infrastructures. This industry can provide a great number of people with job opportunities for employment. The construction industry is known as a productive part which has always contributed to the economy.

At the same time, the construction industry is in an urgent need for improvement of integrity, planning and quality control of production, tendency toward global open economy, realization of open construction systems and standardization of products along with development of the world market. However, government and managers are also aware of how much important development of a robust construction industry is via recent technological improvement in prefabricated buildings and services, so that it could participate in a large scale economy.

Taking into account shortage of ground and its rather expensive price in a metropolis like Tehran, guiding the construction activities toward high-rise construction and mass housing is the path chosen in Iran to control building and housing market.

Traditional construction is taken into account as a common approach which includes frames of reinforced concrete or steel structure with welded joints and also using traditional materials such as brick and treated pottery or joist block ceilings. This method of hard working involves mold making, bending of steel reinforcement bars, concrete pouring and welding. This kind of construction needs numerous professions in site such as carpenters, plaster workers and masons. This procedure could be interrupted by quality issues, improper site conditions, lack of skilled workers and weather conditions. One of the possible choices is to shift toward improvement of selecting the right method of construction in high-rise construction and application of industrial construction systems in the high-rise buildings.

The construction technology has experienced a noticeable progress during the recent years and decades. The issues related to strength of materials, speed of execution, reduced waste of materials, avoiding loss of energy, resistance of buildings against natural disasters, and state of the art management and technologies have been under continuous investigation for a long time in the developed countries which have altogether led to innovations and modern n techniques in the field of construction industry. In Iran, Building and Housing Research Center has initiated extensive actions in the context of modern construction technologies and application of them in the construction industry. Nevertheless, no comprehensive research has been done to select the appropriate method of construction for the high-rise buildings in Iran despite the current urgent need. Therefore, this study tries to identify the most important criteria which are effective for selection of the appropriate construction method of the high-rise buildings with respect to the existing conditions in Iran. This study will then attempt to introduce the best method for construction of the high-rise buildings using multiple-criteria decision making method of AHP with its final goal being scientific application of a selection algorithm for construction of high-rise building projects. Additionally, this research work will discuss about identification of the effective factors and using it in selection of the construction method for the high-rise buildings.

2. Literature Review

Decision Making Methods: Multiple-criteria decision making methods are a part of operation research, which have experienced a very fast growth during the recent two decades. The multiple-criteria decision making methods rank a number of tangible choices based on the multiple criteria starting from the best to the worst one. This approach also investigates theory and methodology of complicated problems in the fields of management, business, engineering and other fields of human activities (Noorzai et al., 2013). MCDM is the technical term used for a set of decision making methods which tries to solve the problems with multiple criteria and choices by the means of a quantifying approach. The real-world problems are rarely single-criteria and single-objective; they rather include an extensive range of criteria which are sometimes even in contrast with each other. The MCDM methods can be categorized under two categories of compensatory and non-compensatory. In the compensatory decision models like AHP, TOPSIS, ELCTRE, PROMETHEE and ANP weakness in a criterion can be compensated by strength of another criterion. The non-compensatory models are mainly based on outranking relation which is a binary relationship defined between the two categories of choices (Golabchi and Noorzai, 2013).

Since taking the correct and timely decision about the construction method used for building the high-rise projects can significantly impact future success of these projects, existence of a robust technique in this regard seems really necessary. One of the most effective techniques is AHP which was introduced for the first time by Thomas L. Saaty in 1970s (Saaty, 2003). The priorities (weights) are based on pairwise comparisons in the AHP technique which enables the managers to test different scenarios. AHP has an up-down linear structure with no down-up relationship and also no internal dependence between elements (Horenbeek and Pintelon, 2013) (Noorzai, 2010).

It can thus be declared that the AHP is one of the most comprehensive systems designed for decision making with multiple criteria and has the ability to formulate the problems considering qualitative and quantitative criteria which is based on a pairwise comparison and enables a sensitivity analysis on the criteria and sub-criteria. Furthermore, it demonstrates the compatibility and incompatibility of the decision which is an important advantage of it in the multiple criteria decision making based on axioms (Saaty and Vegas, 2000).

3. Background

The construction industry is naturally dynamic and the concept of project success is somehow exposed to some ambiguous definitions therein. There are still a great number of researchers who show a kind of sensory and intuitive attitude and try to manage and allocate the resources within various phases of the project (Freeman & Beale, 1992).

Off-site industrialization has been initiated in US by Henry Ford. This is known as a major evolution in the field of construction which was later transformed into a phenomenon and extended to other areas of the world during time and by recognition of its different features. A review on the studies conducted in UK and Australia indicates that these two countries share many similarities based on different research approaches and also categorization of the off-site systems. Malaysia which has taken mass housing as one of the main strategies based on a mid-term planning for development, has itself adopted the advanced approach which was previously examined by other countries (Kayson Construction Company, 2014).

In US, the off-site industrialization in the construction industry has been known as off-site construction techniques. However, modern construction methods is a technical term in UK and used by the government to describe a number of innovations in the field of housing which often incorporate the off-site techniques.
The expression off-site industrialization is used in the construction industry of both Australia and UK. The definition used in Malaysia for the off-site industrialization in this industry is usually called industrial construction system (IBS Roadmap, 2003).
The movement of Malaysia toward industrialization of construction can be due to the rush of foreign labor force to attend jobs in manual building construction. It is interesting to note that the number of foreign workers in Malaysia has increased from 0.5 million people in 1984 to 0.63 million in 1997. Meanwhile, some statistical reports recently issued by this country shows that 2.4 million people in 1998, 1.9 million in 2006 and 2.2 million in 2007-2008 were working for building industry of Malaysia.
It is expected that industrialization via mechanization, automation and prefabrication could decrease the number of foreign workers and be finally replaced with properly skilled local labor. This has been supported in a new economic model of Malaysia in terms of a national strategy (Ngowi et al., 2004).
Zavadskas et al. (2013) used AHP and SWOT analyses to develop a method for project management, which makes its selection based on the current method and also possible techniques for the future. After weighing of the criteria, classification of these criteria is done by using permutation in order to classify the choices according to their priorities.
Ishizaka and Labib (2011) reviewed developments of the AHP approach from its first introduction. Their research was mainly focused on methodological developments to applications of AHP. Some important areas of work for the AHP approach were investigated by them including pairwise comparisons, judgment comparisons, compatibility rates, composition of weights, sensitivity analysis and etc. At the end they argued that some methods of decision making are more accurate though at the expense of being complex and intangible, and equilibrium must be made between intact modeling and applicability of the model. Therefore, they identified the AHP approach as an appropriate method in this equilibrium which has numerous applications from the past to the present.
Mela et al. (2012) employed some methods of decision making to investigate their efficiency and the results obtained from them. For this purpose, six methods namely weighted sum, weighted product, VIKOR, TOPSIS, PROMETHE II and a processes based on PEG-theorem were compared with each other. In this study, the best method of multiple criteria decision making was not determined, but performance of each of them was explained.

4. Research Method

For such a comparison, one may need to collect information from the decision makers. This will enable the decision maker to concentrate just on the comparison of two criteria or two choices without any intervention or interference from outside. In addition to this pairwise comparison, since the participant only evaluates two factors with each other, regardless of the other factors, he/she will provide valuable information for this problem and make the decision making process reasonable. After reviewing the information of the questionnaires, one must make sure about reliability of them which can be evaluated by calculation of the incompatibility rate (IR) that must be smaller than 0.1. The IR is

calculated using the software. The following will explain how to organize the model obtained in this paper (Mahdi and Alreshaid, 2005).

4.1 The model of Analytic Hierarchy Process

In this paper, Expert Choice (EC) software has been utilized to make the model based on AHP technique.

4.1.1 Identifying the Importance of the Criteria and Ranking the Options by Expert Choice software

AHP provides a structure for organization and evaluation of the importance of different criteria and preference of choices for the decision makers, in order to facilitate the decision making process (Nikmardan, 2007). The EC software is basically designed for analysis of the multi criteria decision making problems using the AHP technique and can be run on PCs.

Moreover, this software has many other capabilities, for example in addition to its ability for designing hierarchy diagram of decision making, questions for determination of preferences and priorities and calculation of the final weight, it has the ability to analyze sensitivity of decision making against to changes in the problem parameters.

More important is that the EC software benefits from appropriate diagrams and graphs to present the results and performances in order to make a simple and user friendly connection with the user. This software is also supported by Professor Saaty, inventor of the AHP method. Development of the model based on the AHP method by using the EXPERT CHOICE software includes the following steps:

- making the hierarchy model
- giving the ability of group decision making to the model
- pairwise comparison of the criteria and sub-criteria to address their importance in decision making
- synthesis and combination to find the best choice
- implementation of sensitivity analysis

First Stage: Making the Hierarchy Model:

Any decision making in the EC begins with a model in the form of a hierarchy or tree. Development of the model begins from zero or target level and is extended downward to lower levels of the hierarchy of criteria, sub-criteria and choices. Figure below illustrates the hierarchy made for this study including target (selection of proper method for construction of high-rise buildings with AHP approach, a case study of Tehran), choices (5 methods of construction) and criteria (15 criteria).

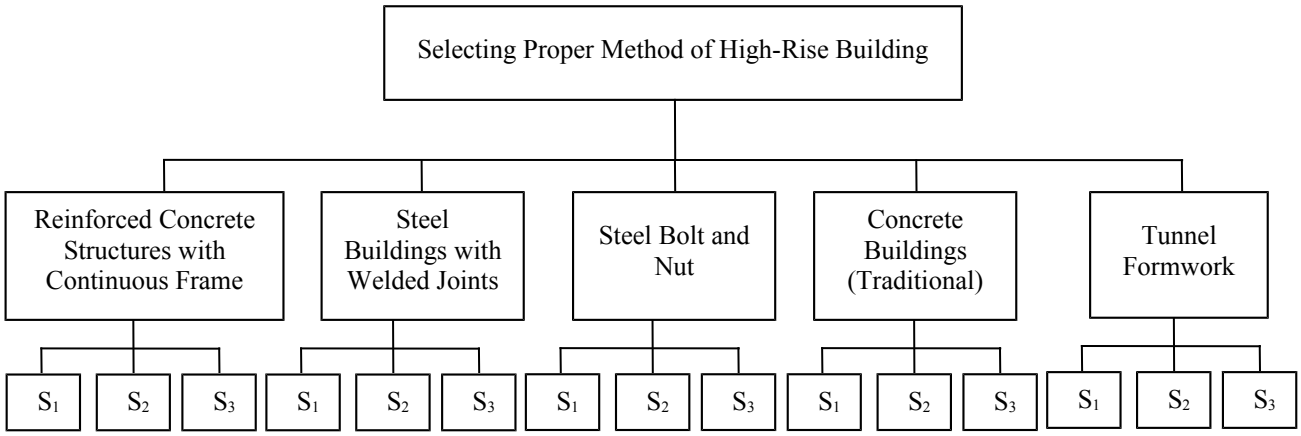

Figure 1- Research Analytic Hierarchy Including the Goal, the Options and the Criteria

Second Stage: Paired Comparison of Criteria

The criteria effective in selection of the correct method for construction of the high-rise buildings were identified to be used in the following.

A- Effective Factors on Selection of Method for Construction of High-rise Buildings

As discussed before, 15 effective criteria were identified for selection of the construction method of the high-rise buildings in order to be used for making the related model.

Table 1- Effectiveness of the Identified Criteria on Method of Selection for Construction of High-rise Buildings

Number	Selection Criteria	Steel Bolt and Nut	Steel Buildings with Welded Joints	Concrete Buildings (Traditional)	Tunnel Formwork	FrameReinforced Concrete Structures with Continuous
1	possibility to provide quality of construction	7.33	5.38	5.85	7.90	5.38
2	possibility to reduce costs of construction	5.23	6.09	5.71	6.57	5.76
3	To be lightweight structure and high resistance-to-weight ratio	7.42	6.09	7.57	7.04	5.23
4	greater speed of construction for the whole project	7.09	5.80	7.76	6.76	5.42
5	flexibility in architecture design (possibility to design in various and desired forms)	3.66	5.61	8.19	6.38	5.19
6	simple execution and possibility to reduce complexity of the project	4.14	7.28	7.80	5.85	4.09
7	less problems in execution of the finishing operations and	7.04	6.23	6.80	7	5.90

	utilities					
8	possibility to supply acoustic and thermal requirements (sound and heat insulation)	8.0	5.14	6.28	7.14	5.38
9	need to a smaller workshop area	6.61	6.28	6.90	7.47	5.76
10	ability to extensive planning and scheduling activities	5.19	4.57	6.42	7.95	5.33
11	Ease to repair and maintenance during operation	5.47	5.95	7.33	5.09	5
12	possibility to supply more beautiful view	5.80	5.80	4.76	5.90	5.42
13	possibility to reduce materials waste	5.28	5	5.38	5.66	5
14	possibility to provide safety in workshop	5.95	6.71	7.85	5.14	6.23
15	Environmental sustainability	5.19	5.76	7.80	4.95	5.23

B- The Importance of Options

Table 2- The Importance of Options in Case Study

Number	Selection Option (Goal Description)	The Importance of Selection Option With Oral Terms (Qualitative)	The Importance of Selection Option With Oral Terms (Quantitative)
1	Steel Bolt and Nut	Relatively strong importance	6
2	Steel Buildings with Welded Joints	Strong importance	5
3	Concrete Buildings (Traditional)	Very strong importance	7
4	Tunnel Formwork	Extreme importance	9
5	Reinforced Concrete Structures with Continuous Frame	Moderate importance	3

C- Calculation of Weight

A pairwise comparison is conducted on the obtained criteria to calculate their weights below:

Table 3- Quantity of Comparison of Criteria

The number of selection criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	3.9	1.9	4	3.1	5.6	3.3	3.1	3.6	2.6	4.2	3.7	4	4.4
2		1	4.1	1.6	6.1	4.7	6.2	5.4	5	5.8	5.8	5.4	4.5	5	5
3			1	1.1	4.7	2.9	4.1	2	4.8	2.7	3.4	3.4	4.3	3.3	4.3
4				1	6.2	4.9	6.5	4.9	5.4	5.5	6.3	5.8	6.6	4.5	4.2
5					1	1	3.6	1	2.8	3.1	2.9	2.8	3.6	2.9	3.3
6						1	2	1	3.3	2.2	3.8	3.3	3.6	2.6	2.2
7							1	0.9	1	1	3.3	4	3.1	4.2	4.1
8								1	3.9	3.6	3.9	3.9	4.4	3.9	4.1
9									1	1	4.1	4	3.8	3.6	3.4
10										1	1	3.3	5.9	4.7	4.3
11											1	1	2.6	3.5	2
12												1	2.4	2.7	2.3
13													1	1	1.7
14														1	2
15															1

Third Stage: Synthesis (Combination) and Conclusion using Expert Choice Software

Having compared and calculated relative weights of the choices and criteria in a pairwise form, it is necessary to calculate the final weight for each of the choices. For this purpose, synthesis operation is utilized which is can be done on either whole model or a part of it. The synthesis may also be examined in two modes, i.e. ideal and distributive.

In the ideal mode, weights of the choices are first divided by weights of their most important ones in order to find the final weight. Then, the obtained number is multiplied by the obtained weight of criterion and summed together with the values obtained for each of the choices, in order to assign a number to each of the choices. Figure 2 depicts the results obtained from the ideal synthesis (summary), while Figure 3 illustrates the results obtained from the distributive synthesis for the preferred choice of construction method of the mass housing projects based on the identified criteria.
Furthermore, the importance of effective criteria in selection of the appropriate method for the construction projects of high-rise buildings can be seen in Figure 4 based on the obtained weights.

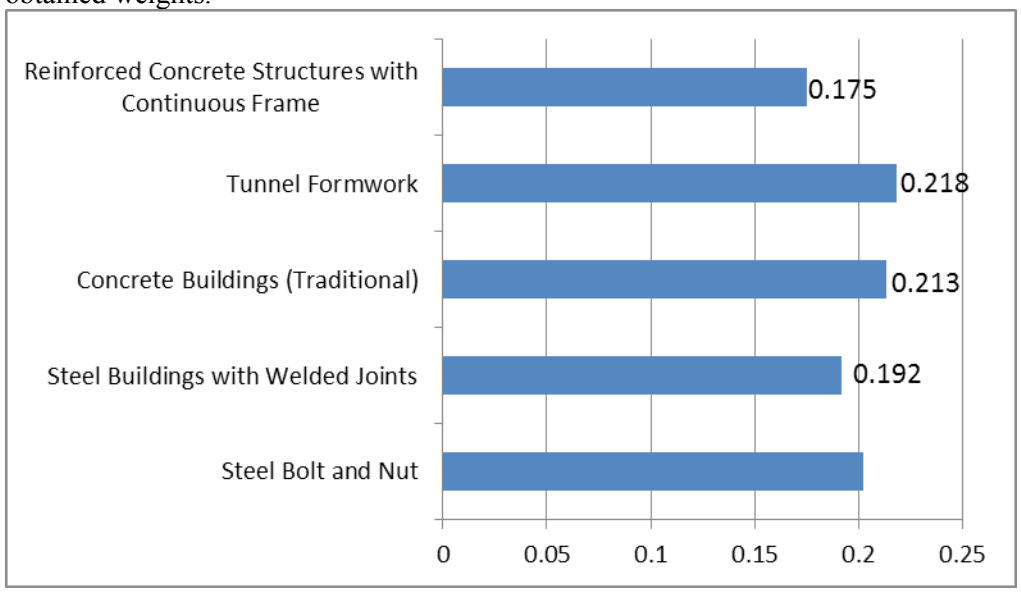

Figure 2- Obtained Results from Ideal Synthesis (Summary), the Weight of Each of Building Method Options Based on Identified Criteria

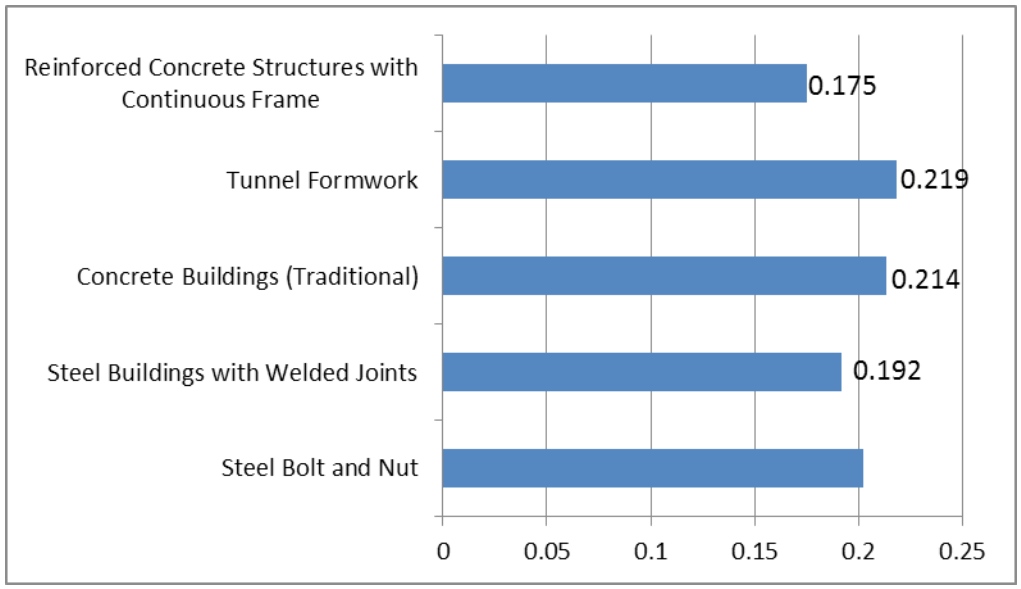

Figure 3- Obtained Results from Distributive Synthesis (Summary), the Weight of Each of Building Method Options Based on Identified Criteria

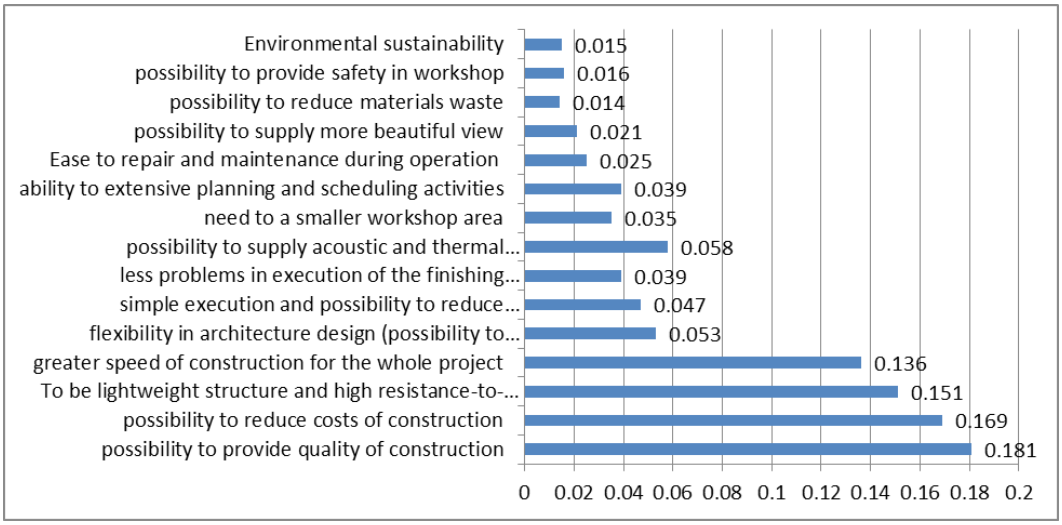

Figure 4- The Importance of Criteria in Selecting Proper Method of High-Rise Building Based on Obtained weight

5. Results

A literature review was provided in this study first and appropriate industrial systems of various kinds were examined to construct the high-rise buildings and to investigate its characteristics. Afterwards, an effective criterion for selection of the proper construction method in the mass housing projects was collected and determined using the literature and experts' viewpoints. At last, the effect of each of the characteristics which were obtained based on five main methods (i.e. Steel Bolt and Nut, Steel Buildings with Welded Joints, Concrete Buildings (Traditional), Tunnel Formwork, Reinforced Concrete Structures with Continuous Frame) was studied in a general review. Thereby, the appropriate method of construction was determined for these projects. Almost all valuable references have been used in this research, along with extensive field studies.

The results of this research reveal that:

The current research work is a field study the results of which have been collected using questionnaires. These questionnaires have multiple choices and were of closed type. They were filled by members of the statistical population and analyzed by AHP approach. The following conclusions can be made considering the results obtained from Expert Choice software:

A- The most important characteristics of the modern systems applicable for Iran and suitable for construction of the high-rise buildings are listed below which are also effective on the method of construction:

1. Tunnel Formwork
2. Concrete Buildings (Traditional)
3. Steel Bolt and Nut
4. Steel Buildings with Welded Joints
5. Reinforced Concrete Structures with Continuous Frame

B- The final ranking of the construction methods for the high-rise buildings in Tehran are summarized below based on the results of research:

1. possibility to provide quality of construction
2. possibility to reduce costs of construction
3. To be lightweight structure and high resistance-to-weight ratio
4. greater speed of construction for the whole project
5. possibility to supply acoustic and thermal requirements (sound and heat insulation)
6. flexibility in architecture design (possibility to design in various and desired forms)
7. simple execution and possibility to reduce complexity of the project
8. less problems in execution of the finishing operations and utilities
9. ability to extensive planning and scheduling activities
10. need to a smaller workshop area
11. Ease to repair and maintenance during operation
12. possibility to supply more beautiful view
13. possibility to provide safety in workshop
14. Environmental sustainability
15. possibility to reduce materials waste

References

1. Freeman, Mark, Beale, Peter (1992) Measuring project success, *Project management journal*, v. 23, no. 1, p. 8-17.
2. Golabchi, Mahmood, Noorzai, Esmatullah, (2013) *Projects Delivery Methods*, University of Tehran Press, Tehran, Iran
3. Horenbeek, Adriaan Van, Pintelon, Liliane, (2013) *Development of a maintenance performance measurement framework—using the analytic network process (ANP) for maintenance performance indicator selection*, Omega, Elsevier
4. Mahdi, Ibrahim M., Alreshaid, Khaled (2005) Decision support system for selecting the project delivery method using analytical hierarchy process (AHP), *International Journal of Project Management*
5. IBS Roadmap 2003-2010 (2003), *Construction Industry Development Board (CIDB)* Malaysia, Kuala Lumpur
6. Ishizaka, Alessio and Labib, Ashraf (2011). Review of the main developments in the analytic hierarchy process. *Expert Systems with Applications*
7. Kayson Construction Company (2014) *Optimization of Construction Method of Kayson Company's Mass Housing*, employer: Faculty of Engineering of Tehran University
8. Mela, Kristo, T. T., Markku Heinisuo (2012). Comparative study of multiple criteria decision making methods for building design. *Advanced Engineering Informatics*.
9. Ngowi, A.B., Pienaar, E., Talukhaba, A. and Mbachu, J. (2004) The globalization of the constructionindustry- a review. *Building and Environment* 40: 135-141. DOI: 10.1016/j.buildenv.2004.05.008
10. Nikmardan, Ali (2007) *The Introduction of Expert choice Software*, AmirKabir University Press, Tehran, Iran
11. Noorzai, Esmatullah, Gharouni Jafari, Kobra, Farhang Moghadam, Babak, Vahedi, Babak, (2013). OPTIMAL SELECTION OF IRAN RAIL PROJECTS PRIVATE

PARTNERSHIP FINANCING METHOD USING AHP METHOD, *The 6th Civil Engineering Conference in Asia Region (CECAR6)*

12. Noorzai, Esmatullah (2010) *Method of absorbing foreign investment with the purpose of raising finance for infrastructure projects in developing countries*, Master Thesis in Project Management, University of Tehran, Iran
13. Saaty, R.W. (2003) *Decision Making in Complex Environment: The Analytic Hierarchy Process (AHP) for Decision Making and the Analytic Network Process (ANP) for Decision Making with Dependence and Feedback*, Super Decisions, Pittsburgh.
14. Saaty, T. L., and Vargas, L. G. (2000). *Models, Methods, Concepts and Applications of the Analytic Hierarchy Process.* Kluwer Academic Publishers, Boston
15. Zavadskas, Edmundas Kazimieras, Antucheviciene, Jurgita, Šaparauskas, Jonas, Turskis, Zenonas (2013) Multi-criteria Assessment of Facades' Alternatives: Peculiarities of Ranking Methodology. *Procedia Engineering*