ASSESSMENT OF EFFECTIVE FACTORS ON TIME, COST AND QUALITY OF MASS HOUSE BUILDING PROJECTS USING ANALYTIC HIERARCHY PROCESS- A CASE STUDY IN TEHRAN

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ABSTRACT

Increasing demand for house building in Iran resulting from various factors such as increase in the young population of the country and capital-oriented approaches to the house building issue has led to propose different methods to remove this major demand. The best current solution can be characterized as mass house building which is in fact industrialization of construction procedures. Similar to any other civil and infrastructure projects, several factors affect obtaining project objectives, namely time, cost and quality in the mass house building projects (MHBPs). In this research, effective factors have been identified and classified into three main groups including factors due to the project organization (POR), project specifications (PSP) and project environment (PEN). Then, the effective factors have been evaluated using Analytical Hierarchy Process (AHP) according to the three criteria, i.e., time, cost and quality. Finally, due to the variable nature of criteria, sensitivity analysis has been conducted. The obtained results clearly revealed that the most important factors in three groups of POR, PSP and PEN are financial capability; project design and project finance; and market condition, respectively.

Keywords: Project Management, Mass House Building Projects, Analytical Hierarchy Process (AHP), Sensitivity Analysis

1-Introduction

One of the major problems of developing countries in successful implementation of civil and infrastructural projects leading to destruction of financial and human resources is lack of employing project management methods by high-ranked managers of organizations. Since housing supply in Iran is less than its demand, mass house building projects (MHBPs) can be characterized as an appropriate approach to balance between supply and demand. On the other hand, the role of mass house building projects on the activation of other industries should be considered.

Obtaining the main objectives of mass house building projects including time, cost and quality is a part of corresponding project managers' responsibilities. For instance, factors such as reducing the elapsed time between gaining the construction permission and the final project delivery, preventing excess cost of human resources, machinery and materials, enhancing the quality of materials in accordance with standards and technical criteria can be characterized as effective factors.

In this paper, effective factors first have been identified using Delphi method and classified into the following three main groups:

1- factors due to the project organization (POR)
2- factors due to the project specifications (PSP)
3- factors due to the project environment (PEN)

Then through using analytical hierarchy process and pairwise comparison according to the time, cost and quality criteria based on expert judgment, the weight of factors and groups of factors have been determined and ranked according to the degree of their influence on the project success. Finally, since judgment is made based on a limited number of experts, sensitivity analysis has been conducted on the results and the effect of changes in the importance of criteria on the ranking has been investigated.

2-Mass house building projects in Iran

The term "mass house building projects" in the construction industry is called to the projects in which mass production methods are employed to construct house units. This description adopted by different researchers has been derived from manufacturing sector [1]. However, this definition may not clarify some important aspects of such projects including project environment, region topography, bulk materials and special design considerations. Therefore, a comprehensive definition that covers all major characteristics may be described as follows: MHBP is design and construct of standard and typical house units normally implementing at the same time and the same location[2].These house units can include terrace; multistory and tower blocks; and semidetached or detached residences.

An important issue in the design and implementation of mass house building projects is learning curve theory. According to this theory, each time that the number of repetition doubles, the cumulative production rate (manhour per unit) declines by a consistent percentage of the previous cumulative production rate. When this theory was replicated in the construction industry using 45 identical house-units, it was confirmed that each time the house-units doubled the cumulative production rate improved by 90%. This suggests that a minimum of two house-units is sufficient to achieve learning curve effect arising out of the repetition involved in MHBPs (Schwartzkopf 1985).

The United Nations Economic Commission had stated that for developing countries to meet their present and future housing needs, they should aim at an annual production rate of 10 house-units per 1000 population (Edmonds and Miles, 1984).

MHBPs as one of the greatest project-oriented sectors in construction industry play a significant role in countries with developing economy. Such projects have the greatest contribution in GDP and include about 60% of the total construction projects [4].

In Iran due to the significant role of housing sector and its interaction with Iran's macroeconomics, it can be stated that 20 to 30 percent of country's budget is devoted to this issue each year. The contribution of building industry to employment in Iran is beyond 11 percent. Therefore, there is a close relationship between housing and other industrial sectors. Building industry may be affectd by other industries and it may also affect them too.

At present, demand of housing is more than its supply. This demand can be classified into two main groups: 1) actual demand of building due to the household demand 2) capital demand. What distinguishes housing market from other markets is the capital demand in which people purchase houses hoping maintain or increase the value of their capital [5].

According to the peak of population pyramid in Iran, increasing trend of population and its resultig demand , a large number of house units should be constructed within 20 years. Based on the conducted surveys, in order to make balance in the building market, 1.4 million house units should be constructed annually [6].

To achieve this, the best approach is industrial production or mass house building. In order to achieve the objectives of MHBPs successfully including time, cost and quality, the management of such projects has become extremely important. This is because the MHBPs in Iran encounter the following problems: prolongation of implementation period, weak control on their cash flow, lack of sufficient quality in accordance with standards and technical criteria and customer's satisfaction. Therefore, identification of effective factors on these projects seems necessary.

Ahadzie et al. (2008) concluded that special systematic studies have not been conducted in relation with the classification of performance of project managers in MHBPs. Hence, experienced project managers face with lack of knowledge that could be possibly useful for their continuing professional development (CPD) leading them to the best practice [3].

In the current study, the effective factors on the mass house building projects in Iran have been identified and classified. Then, they have been ranked using AHP based on expert judgment and finally sensitivity analysis has been conducted on the obtained results.

3- Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process developed by Thomas L. Saaty in 1980 is a method to solve the problems of multi criteria decision making in which both qualitative and quantitative criteria can be considered. This method is based on the pairwise comparison and facilitates the process of judgment and calculations. In general, AHP may be applied to the problems of ranking, selection, evaluation and prediction in which decision making is required. Moreover, AHP has the capability of being combined with other methods and integrated AHP has received noticeable attention in recent years [7].

Ghodsypour and O'Brien (1998) employed an integration of Analytic Hierarchy Process (AHP) and Linear Programming (LP) in supplier selection and weighing process using three criteria i.e., time, cost and service [8].

Other applications of AHP include integration with meta-heuristic algorithms such as genetic algorithm (GA) and artificial neural network (ANN). Kuo et al. (2002) employed integration of fuzzy AHP and ANN for selecting convenience store location. The factors considered in this study include competition, attractiveness, convenience, easy access and features of store and population [9].

One of the advantages of AHP can be assigned to its simple structure. This is because it has been designed in a way that adopts human mind and nature. This procedure includes a number of individual judgments weighting in a rational way. According to the Miller's Law, an individual normally can compare only 7±2 items at the same time. AHP improves the quality of decision making through providing pairwise comparison between criteria and alternatives. AHP, in fact, creates the chance of searching and evaluating the cause and effect relationship between goal, criteria, subcriteria and alternatives using breaking down the structure of the problem [10].

A typical AHP problem including 3 criteria, 8 subcriteria and 4 alternatives is schematically illustrated in figure 1.

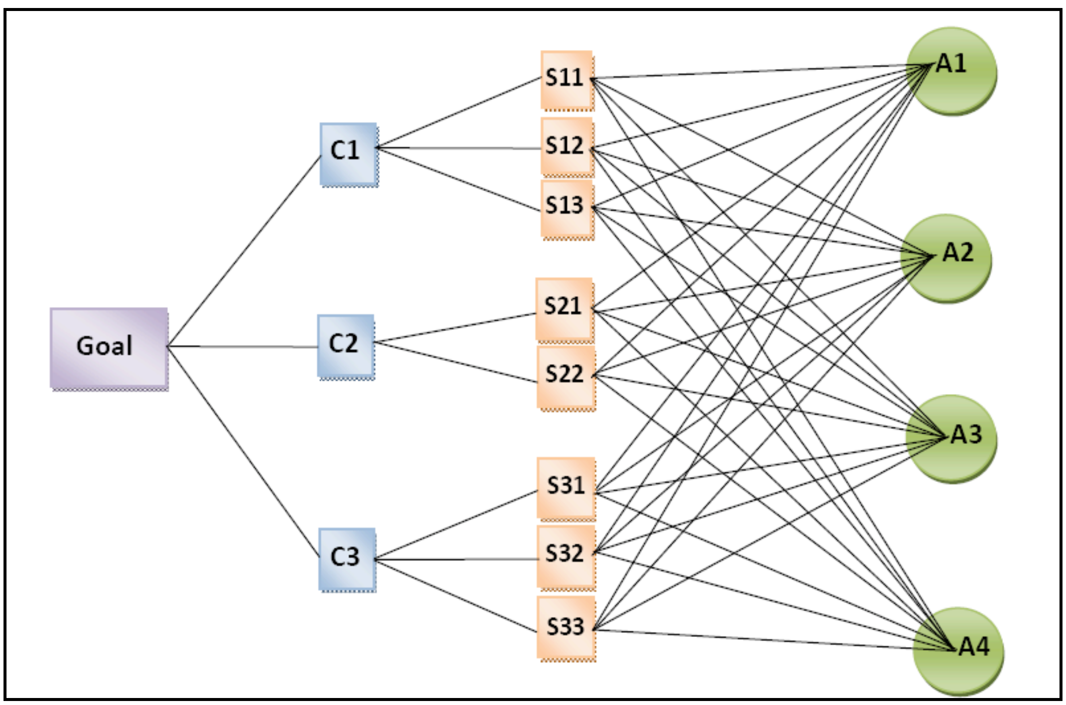

Figure1. A typical AHP problem including 3 criteria, 8 subcriteria and 4 alternatives

Ho et al. (2006) presented the flowchart illustrated in figure 2 representing the general procedure of Analytical Hierarchy Process [11]:

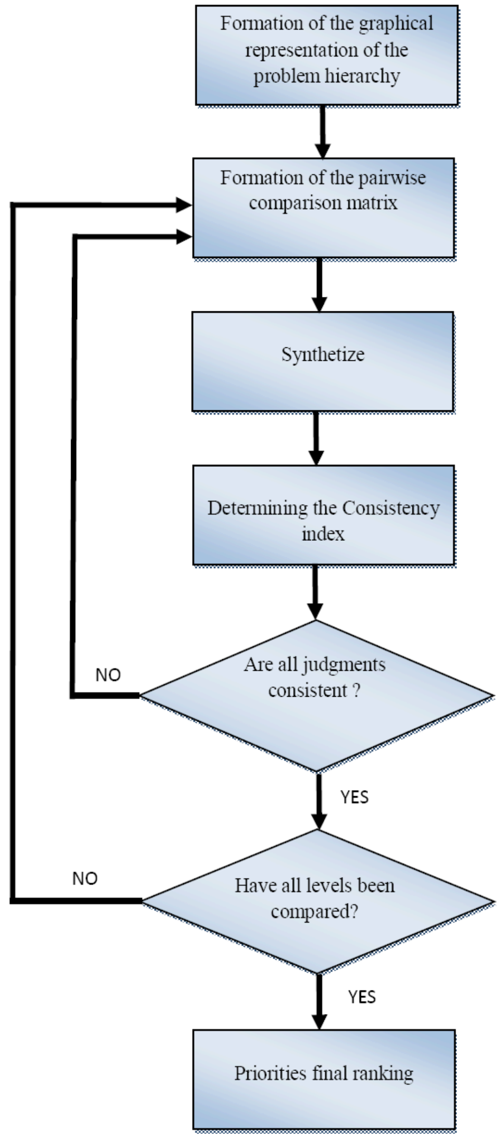

Figure 2. Flowchart of Analytical Hierarchy Process (Ho et al. 2006)

The procedure can be summarized as follows:

Step 1- Developing the decision tree or hierarchy structure which is in fact the proper definition the problem and goal. Then the levels of criteria are determined and finally, the alternatives are evaluated in the lowest level of the hierarchy structure.

Step 2- making pairwise comparison of criteria and forming matrix of pairwise comparison. The entries of this matrix represent priorities (weight, importance, effectiveness or value). For instance, if there are n criteria at each level, an n×n matrix will be formed. Entry a_{ij} represents the priority of criterion i on criterion j with respect to the problem objective.

Step 3- Comparing alternatives in relation to different criteria and forming matrix of pairwise comparison. The obtained results can be expressed by numbers. For this purpose, the proposed scale by Saaty has been used. These values are illustrated in table 1. Even numbers between odd numbers show the average limit of defined scale.

Table 1. The fundamental scale for pairwise comparisons (Saaty, 1980)

Definition	**Intensity of Importance**
Equally preferred	1
Moderately preferred	3
Strongly preferred	5
Very strongly preferred	7
Extremely preferred	9

Step 4- Determination of inconsistency index of matrices obtained from the two previous steps: Decision makers should reconsider their pairwise comparisons if inconsistency index exceeds the allowable limit. Saaty suggested the allowable limit to be 0.1.

Step5- Normalizing the obtained matrices from previous steps: In this regard, all entries of each column should be divided into the sum of that column to determine the normal value of each entry.

Step 6- Calculating the row average of normalized matrices: The average of entries at each row represents the weight and importance of each alternative with respect to the related criteria.

Step 7- Forming decision making matrix: The entries of this matrix are obtained through product of weight of each criterion and weighting vector of alternatives. The rows and columns of this matrix are related to alternatives and criteria, respectively. The sum of each row represents the score of each alternative.

Step 8- Concluding and conducting sensitivity analysis (if needed): after determining the score of alternatives, they are organized in ascending or descending order and the best alternative is selected. In addition, in order to study the effect of changes in the importance of criteria on the selecting favorable alternatives, sensitivity analysis has been conducted.

Software packages like Expert Choice and Automan have been developed based on AHP and are extensively used. In this study, Expert Choice V11 has been employed due to its advantages including user friendly environment, evaluation of inconsistency of judgments, sensitivity analysis, network graphic design, etc.

4. Research methodology and obtained results

In this paper, first the effective factors on the aims of mass house building projects have been identified using Delphi method. This method, in fact, is a systematic method to collect information about a particular subject and also provides the opportunity to communicate between experts [12].
Then, these factors were classified into three main categories:

1. factors due to the project organization (POR)
2. factors due to the project specification (PSP)
3. factors due to the project environment (PEN)

Thereafter, Analytical Hierarchy Process (AHP) has been employed so as to evaluate and rank the effective factors on the mass house building projects. Criteria considered in the modeling include time, cost and quality. After pairwise comparison between criteria and alternatives from the aspect of expert including five experienced project managers of MHBPs, the most important factors were determined.
Finally, sensitivity analysis has been conducted to investigate the effect of changes in the criteria on the ranking.

Figure 3 shows the hierarchy structure of the problem. The objective was to rank effective factors on the success of mass house building projects. Next level is allocated to the three mentioned criteria. Factor groups including POR, PSP and PEN are positioned in the third level and finally all the factors obtained from the Delphi method are placed in the lowest level of the model.

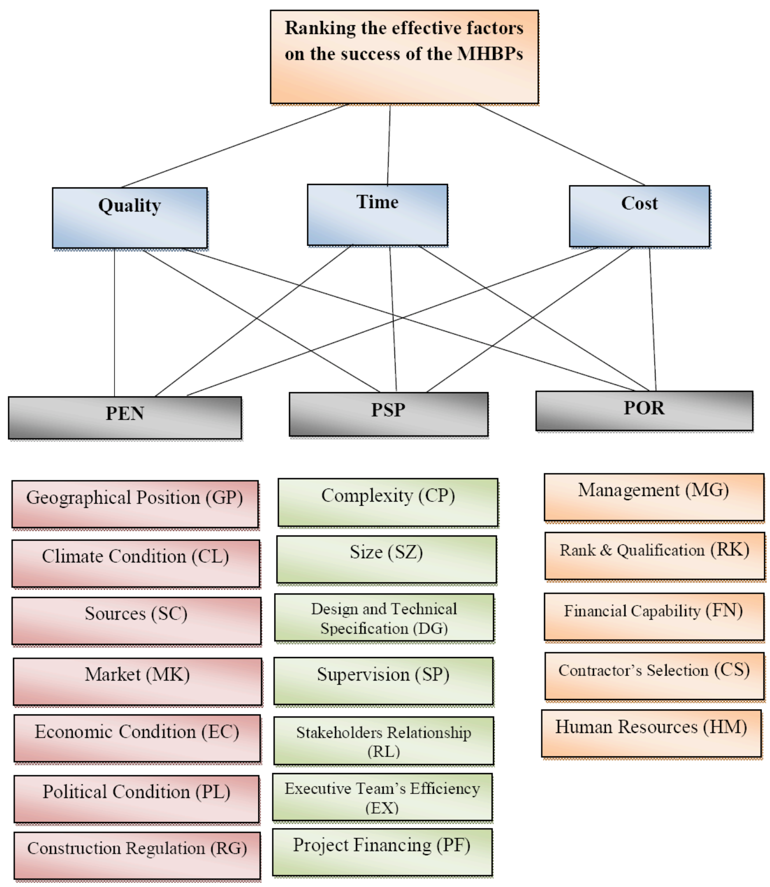

Figure 3. The structure of AHP model in the ranking of effective factors on the cost, time and quality of MHBPs in Iran

After modeling, pairwise comparison between criteria factor groups and factors were conducted using proposed scale by Saaty. The results are given in tables 2 through 8. In these tables, each entry represents the priority of corresponding column on corresponding row.

Table 2. The priority of criteria with respect to the effect on the success of MHBPs

	time	**cost**	**quality**
time	1.000	0.250	0.500
cost	4.000	1.000	2.000
quality	2.000	0.500	1.000

Table 3.Pairwise comparison between factor groups with respect to effect on the quality of MHBP**s**

	PEN	**PSP**	**POR**
PEN	1.000	0.200	0.500
PSP	5.000	1.000	3.000
POR	2.000	0.333	1.000

Table 4.Pairwise comparison between factor groups with respect to effect on the time of MHBP**s**

	PEN	**PSP**	**POR**
PEN	1.000	0.333	1.000
PSP	3.000	1.000	2.000
POR	1.000	0.500	1.000

Table 5.Pairwise comparison between factor groups with respect to effect on the cost of MHBP**s**

	PEN	**PSP**	**POR**
PEN	1.000	0.143	0.500
PSP	7.000	1.000	5.000
POR	2.000	0.200	1.000

Table 6.Pairwise comparison between factors with respect to the importance in PEN

	GP	**CL**	**SC**	**MK**	**EC**	**PL**	**RG**
GP	1.000	0.500	0.250	0.143	0.500	1.000	1.000
CL	2.000	1.000	0.333	0.200	0.500	1.000	1.000
SC	4.000	3.000	1.000	0.250	2.000	2.000	3.000
MK	7.000	5.000	4.000	1.000	4.000	5.000	6.000
EC	2.000	2.000	0.500	0.250	1.000	2.000	2.000
PL	1.000	1.000	0.500	0.200	0.500	1.000	1.000
RG	1.000	1.000	0.333	0.167	0.500	1.000	1.000

Table 7.Pairwise comparison between factors with respect to the importance in PSP

	CP	SZ	DG	SP	RL	EX	PF
CP	1.000	0.200	0.200	0.250	1.000	0.250	0.125
SZ	5.000	1.000	1.000	2.000	4.000	2.000	0.250
DG	5.000	1.000	1.000	2.000	4.000	0.500	0.333
SP	4.000	0.500	0.500	1.000	3.000	1.000	0.250
RL	1.000	0.250	0.250	0.333	1.000	0.250	0.143
EX	4.000	0.500	0.500	1.000	4.000	1.000	0.250
PF	8.000	4.000	3.000	4.000	7.000	4.000	1.000

Table 8.Pairwise comparison between factors with respect to the importance in POR

	MG	RK	FN	CS	HM
MG	1.000	3.000	0.200	2.000	1.000
RK	0.333	1.000	0.143	1.000	0.333
FN	5.000	7.000	1.000	7.000	4.000
CS	0.500	1.000	0.143	1.000	0.333
HM	1.000	3.000	0.250	3.000	1.000

After synthetizing the comparisons, weight of criteria, factor groups and factors have been determined locally and globally, the results are depicted in tables 9 and 10.

Table 9. Weight of criteria with respect to the goal, group factors with respect to each criterion

criterion	Weight of each criterion	Factor groups	Weight each factor group
Cost	0.571	POR	0.167
		PSP	0.740
		PEN	0.094
Time	0.143	POR	0.230
		PSP	0.648
		PEN	0.122
Quality	0.286	POR	0.240
		PSP	0.550
		PEN	0.210

The weight of each main class of factors is obtained as follows:

W_{POR}=0.571×0.167+0.143×0.230+0.286×0.240=0.195

W_{PSP} =0.571×0.740+0.143×0.648+0.286×0.550=0.687

W_{PEN} =0.571×0.094+0.143×0.122+0.286×0.210=0.119

Table 10. Global and local weight of criteria and factor groups

Factor groups influencing the success of MHBPs	Weight of factor groups	Factors	Local weight of factors	Global priority
Project organization (POR)	0.195	MG	0.146	0.029
		RK	0.061	0.012
		FN	0.561	0.111
		CS	0.066	0.013
		HM	0.165	0.031
Project specifications (PSP)	0.687	CP	0.033	0.023
		SZ	0.160	0.110
		DG	0.165	0/113
		SP	0.099	0.068
		RL	0.037	0.026
		EX	0.104	0.072
		PF	0.401	0.275
Project environment (PEN)	0.119	GP	0.055	0.007
		CL	0.073	0.007
		SC	0.182	0.022
		MK	0.438	0.052
		EC	0.118	0.014
		PL	0.070	0.008
		RG	0.064	0.008

Finally, sensitivity analysis was performed on the obtained results. For this purpose, changes in the weight of factors were observed when weight of each criterion varied from 0 to 100. This is illustrated in figure 4.

5. Discussion and conclusion

According to table 9, it can be seen that the most important criteria from the aspect of experts are cost (0.571), quality (0.286) and time (0.143), respectively. Also, the most important factor groups are PSP (0.687), POR (0.195) and PEN (0.119), respectively.
Among 19 identified factors in the last column of the table 10, the most five effective factors are as follows:

1. Project Financing (0.275)
2. Design and technical specifications of the project (0.113)
3. Financial capability of the project organization (0.111)
4. Size of the project (o.110)
5. Efficiency of the project executive team (0.072)

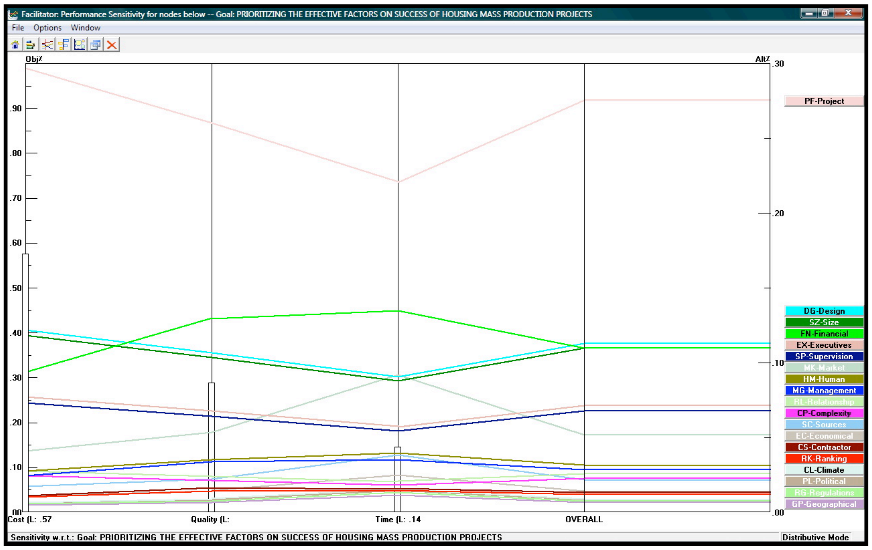

Figure 4. Sensitivity analysis of effective factors on the success of MHBPs in Iran

As shown in the chart, gradual increase in the cost led to increase in the factors of PSP and decrease in the factors of POR and PEN. Also, the factor of financial provision is remarkably dominant to other factors. The importance of this factor ranged between 0.247 and 0.297 when the importance of cost varied from 0 to 100 percent.

Moreover, with gradual increase in the quality, the importance of factors of PEN did not change considerably, whereas the importance of factors of PSP and POR decreased and increased, respectively. If the importance of quality reaches to 100 percent, project financing and financial capability will have the greatest weight equal to 0.26 and 0.13, respectively.

Finally with increase in the importance of time, it was seen that contrary to PSP, factors of POR and PEN increased. If the importance of time reaches to 100 percent, the obtained ranking changed and is listed as follows:

1. Financial provision (0.221)
2. Financial capability of the POR (0.135)
3. Supply and demand in building (0.092)
4. Design and technical specifications of the project (0.091)
5. Size of the project (o.088)

Based on what mentioned, it can be concluded that in order to obtain main objectives in the MHBPs, some effective factors should be taken into account. The most important factor is characterized as project financing. In addition, financial capability of the project organization plays a significant role in the success of the project and finally design and technical specifications of the project may also affect the project objectives. Therefore, the above mentioned factors should be considered so as to successfully implement MHMPs.

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