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Application of AHP-MCDM Method to Estimate the Delay-time of Tabriz-Bonab Highway Project

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ABSTRACT

Road construction projects are considered as the largest infrastructure projects in Countries, which always face the most problems in construction. The longitudinal extent of the projects has caused them to cross different geological conditions and be under different climatic conditions which involvement of various factors in operation of road construction has caused time delays. In this regard, the present study has tried to consider the relationship between factors affecting the project construction and time delay of Tabriz-Bonab road project. For this purpose, the multi-criteria hierarchical analysis (AHP-MCDM) method has been used to prioritize and measure the effective factors in the project. Based on the evaluations, 6 main factors including human, environmental, managerial, technical, infrastructure and technical errors were involved in the project, each of them can be divided into several sub-factors which managerial as well as infrastructure factors have the greatest impact on the project delay and environmental factors have the least impact on the project.

1. Introduction

Since the development of infrastructure is considered necessary for development in all countries, huge investments in this regard are made by governments, companies, organizations, etc. (Zai-qiu, 2008). Road construction projects are considered as one of the largest infrastructure projects in many countries, which always face the most problems in construction and implementation. The longitudinal extent of the projects has caused them to cross different geological conditions and be under different climatic conditions. On the other hand, the management of road construction projects is generally traditional and usually includes various mismanagements in the design to operation stages. A look at the existing records of national development projects shows that in many cases these projects are not completed on time and sometimes the time of its implementation is extended several times. Increasing project execution times is often accompanied by increased direct and indirect project implementation costs, and such a situation often leads to project uneconomicization and widespread waste of national resources. There are many factors that delay the implementation of construction projects, but the effects of these factors are not the same, and some of them have much more severe effects on project implementation time and, consequently their costs. By performing a well-considered and appropriate management which that can identify affective factors in development of project, It can be used as successful plan at the project management. One of the powerful approaches that can be responsive in such situations and cover all aspects of managerial and executive evaluations is the Analytic Hierarchy Process (AHP), which is considered as the most appropriate optimal decision-making method. This approach, by identifying factors and selecting the most important and sensitive criteria independently or dependently, attempts to determine a set of decision matrices in relation to the main criterion, sub-criteria and their specificity for the project under study. This advantage allows the extraction of features and factors

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influencing the occurrence of delays or problems on each individual project (Ravanshadnia et al., 2010).

Road construction projects are of special importance due to the high volume of executive operations and consequently the high volume of financial and human resources, machinery, etc., so in this category, careful planning, management and prevention of waste of resources in order to achieve development goals. Project management and evaluation include the processes involved in guiding risk management planning, identifying, analyzing, responding to, monitoring and controlling risks in a project (Sarkar et al., 2018). By using optimal project management, risks are accurately identified and then analyzed and finally prioritized based on importance. In optimal project management, attitude towards project risk is very important. For this purpose, engineering project management (EPM) methods are generally used to identify problems and issues involved in engineering projects (Razi et al., 2019).

The quality of engineering management is essentially a function of the quality of decision making and decision optimization. If such a utility is not achieved in any way, it will cause various problems (both small and large) and as a result will delay the project. This delay will also cause an economic overload and increase the cost pressure to the project (Greco et al., 2016). AHP approach uses several different criteria for optimal measurement and decision making in a sequential, hierarchical, and paired manner. This causes the most coverage to be paid to the factors influencing an optimal decision management (Nguyen et al., 2015). This approach uses pairwise comparisons of sub-criteria and alternatives to rank and determine the importance of factors in decisions involving several different criteria, which makes it possible to measure dimensionally for all aspects of the decision. In fact, the core of decision-making analysis in the AHP approach, which leads to the selection of the best option or optimal option (with the greatest sensitivity, importance and impact) from several criteria/sub-criteria/alternatives, is pairwise comparison and standard weighting in the matrix. These calculations are usually based on the judgment of the expert force/forces that appear in the form of a pairwise comparison matrix. Any errors and inconsistencies in comparing and determining the importance between options and indicators affect the final result of the calculations and affect the compatibility rate of the decision matrix (Sarkar et al., 2018).

2. Road Construction Project Planning

Transportation has played a key role in the formation of human societies and their economic development since the beginning of human history. In the present age, communication arteries form the basis of any country's economy. Sustainable development, fast and safe transportation, like other aspects of human life, crystallizes when it is systematically and based on scientific logic, in this systematic process that the role and place of transportation science in the sustainable development and economy of societies is manifested (Zhou and Shi, 2009). The growing population, the expansion and development of cities, the increase of migration and extra-urban travel and communication, are among the effective factors in the development of communication networks in order to meet different needs and access to goods, services, resources and commercial and economic activities. The role and function of roads and road construction projects is not limited to the distribution and transfer of goods and passengers and access to resources and services, but from another perspective, is a factor for the emergence and growth of settlements and the development of urban and rural centers; To the extent that in many cases the location of urban spaces is often affected by it, and these spaces are formed with a minimum distance from the road or along it. But the most important role and task of roads is to provide access and communication between two hypothetical and specific points, the characteristics of which largely depend on the relative, spatial and temporal position of these points. However, the final product path is a set of related and dependent processes, consisting of a variety of human activities, methods of preparing materials, using a variety of machines, and so on (Sarkar et al., 2018).

For this reason, achieving goals such as optimal use of resources, achieving appropriate, acceptable performance and quality at the lowest cost and adaptation to existing conditions; Requires the use of evaluation systems based on certain criteria and indicators and various technical and executive considerations in each of the stages of study, design and implementation of various operations of road construction, road infrastructure, pavement, routing, drainage and other factors affecting the cost and time of implementation. Due to the importance and critical role of transportation and communications in achieving development goals and programs in the economic, political, cultural and social sectors and its impact on the growth and development of human activities, the emergence and development of settlements and urban centers, distribution of services and goods. .., the implementation of various road construction projects and projects as the basis and infrastructure of development has a special importance and position (Greco et al., 2016). Some of these features are (Raydugin, 2013):

- High volume of operations and current costs of road construction projects compared to other construction projects,
- The existence of some environmental limiting factors such as regional and climatic conditions, location, the presence of transit traffic and the interference of various urban activities with ongoing road construction projects, which makes the implementation of such projects limited and difficult,
- The importance of time in the implementation of road construction projects,
- The need to pay more attention to investment risk compared to other projects,
- The need to pay attention to maintaining road safety during operations and in order to prevent accidents and traffic accidents.

According to these statements, it can be seen that the volume and scope of road construction projects has always been a factor in the involvement of several problems, the result of such problems in the implementation of projects, delays in the design, implementation and implementation processes (Barker and Pukett, 2013). In general, any action or event that prolongs a contract schedule is called a delay. Delays in the completion of projects and their operation have several disadvantages, including the following (Raydugin, 2013):

- Increase the total cost of direct and indirect project: so that direct costs increase with decreasing implementation period, and indirect costs increase with increasing project duration,
- Capital stagnation and delayed return: means that the return on investment will not happen until the project is operational,
- Long schedule: As the execution time increases, the workload to achieve the project objectives increases, which increases the cost and reduces the quality of execution,
- Loss of relevance and priority: Because some projects are created for a specific time, they may lose their relevance as the execution time becomes longer.

In addition to the above, the prolongation of the project has caused customer dissatisfaction, which is one of the reasons for the failure of projects. Therefore, addressing the causes and factors of project delays and recognizing the factors that cause delays in the implementation process of projects can, on the one hand, help improve the progress of semi-finished projects and provide the ground for their completion, and on the other hand, prevent delays in new projects which to prevent national funds from being suspended. For this reason, gaining experience, maintaining and using it in future projects is very important. Delays in the project implementation system can affect the process stages of their implementation at different times. Delay periods can be the start of the project, the completion of the project and the completion of the projects (Barker and Pukett, 2013). In different countries, depending on social, cultural, political, managerial issues, etc. (Raydugin, 2013), the reasons for the delay are different and varied. After identifying the delays, it is necessary to use a suitable method for analyzing the delays. Each construction project consists of two separate phases; the pre-construction phase is the period between the beginning of the project understanding and the signing of the contract, and the construction phase begins after the contract and the main construction period begins. Delays and cost increases may occur in both periods; but the main reasons for delays and cost increases usually occur during the construction period. There are many reasons for delays and increased costs in construction projects. These reasons range from key parameters such as management and technology to physical, social and financial issues (Barker and Pukett, 2013).

3. Project Risk Management

Project risk management is a valuable component of project management and enhances the value of other project management processes. Like all these processes, project risk management must be implemented in accordance with the existing policies and strategies of the organization. In addition, as with other processes in project management, project risk management must be implemented in a way that is appropriate for the project. Project risk management should identify business challenges as well as the multicultural environment associated with the evolving global environment, which includes collaborative projects with customers, suppliers and workforce around the world. Changes that occur as a result of implementing a project risk management process in a project management program may require decisions at appropriate management levels to allocate people, allocate or modify budgets, commit to others outside the project, interact with legislators, and follow rules. Project risk management should be guided by these internal and external requirements (Chatterjee et al., 2018). Project risk management should always be based on ethical principles and adhere to the ethical codes of project management. Integrity, responsibility, realism, professionalism and fairness in dealing with others are the hallmarks of successful project risk management. Effective project risk management is benefits from strong communication and stakeholder consultation. These strong connections enable stakeholders to agree that project risk management in general and risk identification, analysis, and response in particular should be done rationally and purposefully and should not be influenced by political or irrational issues (Raydugin, 2013).

Project risk management should be implemented in all projects. The degree, level of detail, use of tools and the amount of time and resources used in project risk management should be determined depending on the characteristics of the project being managed and the value they can have on the outputs. Therefore, a large project that is of great value to an important customer than a small, short-term and internal project that can be done along with other tasks and with a flexible schedule theoretically requires more resources, time and attention to risk management (Raydugin, 2013). Each project risk management process should be prepared in the project risk management planning process in accordance with the project under management and in order to check the correctness of the decisions made in the planning stage should be periodically reviewed to be able to make a project successful (Barker and Pukett, 2013). In general, general criteria for the success of project risk management can be expressed as follows (Raydugin, 2013):

- Understanding the value of risk management: Project risk management should be recognized as a valuable activity that brings positive potential return on investment for organizational management, project stakeholders (internal and external), and project management and team members,
- Individual Responsibility/Commitment: Project participants and stakeholders should all take responsibility for risk-related actions. Risk management is everyone's responsibility,
- Open and honest communication: Everyone should be involved in the project risk management process. Any behavioral action that prevents proper communication about project risk reduces the effectiveness of project risk management in terms of preventive approaches and effective decisions,
- Organizational commitment: Organizational commitment is created only if risk management is in line with the goals and values of the organization. Because some risks require approval or response from other management levels above the project manager, project risk management may require more managerial support than other areas of project management,

- Proportional Efforts: Project risk management activities should be consistent with the value of the project to the organization and the risk level of the project, its size, and other organizational constraints. In particular, the cost of project risk management should be commensurate with its potential value to the project and the organization,
- Coordination with project management: Project risk management in a vacuum environment is not separate from other project management processes. Successful project risk management requires the proper implementation of other project management processes.

The present study is defined in order to evaluate and identify the factors affecting the time delay on road construction projects for the engineering management of the Tabriz-Bonab belt project and tries to consider the descriptive-survey evaluation system. Experts and experts will evaluate the factors influencing the time delay in the project. In this regard, by considering the questionnaire system, the effective factors in project delay are identified and the most consistent optimal decision matrix for this project is defined by AHP technique. These decision matrices are used to determine the optimal matrix and derive parametric weights for criteria, sub-criteria and options. Then, using the advantage of process parametric weighting, the impact coefficients are defined for the criteria according to their importance and sensitivity, and each parameter is prioritized according to these impact coefficients. The results will be used to assess the latency of the project.

4. Material and Methods

In this study, considering hierarchical decision-making (AHP) and multi-criteria decision-making (MCDM) approaches, which are one most powerful optimal decision-making approaches for a wide range of variables with uncertainty. Attempts have been made to provide a quantitative model to evaluate and prioritize the factors affecting the time delay of the Tabriz-Bonab belt project as a road construction project located in the East Azerbaijan region. The proposed model takes into account the characteristics of different levels for the ring road range to evaluate and provide an optimal system based on factors affecting risk and delay, especially during the project, which subsequently imposes additional costs on the project and thus returns. In this regard, using the field evaluation approach (interview, questionnaire and spatial evaluation) and expert system consisting of 20 experts and project managers, technical experts, university professors and workshop technicians involved in the site in the region; the criteria and effective factors for creating time delays in the project have been identified. Then, using decision-oriented approaches, AHP and MCDM, decision matrices for these criteria are constructed under the identified sub-criteria (effective factors). These decision matrices are used to extract factor impact coefficients in creating project latency and risk. Strategic plan shown during the levels specified based on criteria and sub-criteria; AHP is classified during internal processes and learning, as shown in Fig. 1 (Greco et al., 2016).

Prioritization and identification of effective factors in causing delays in construction projects are very important at project management levels and are a key weight for proper planning in the optimal implementation of the project. For this purpose, field studies have been prepared as a questionnaire between 20 experts in the field of project management and road construction in East Azerbaijan and the city of Tabriz. Among these, 6 main criteria including human, environmental, managerial, technical and infrastructural factors and also technical errors have been identified which have been used as the basis of evaluations in this study. These items were extracted from the information related to the interviews as well as the questionnaires provided between the specialized forces as a standard. Table 1 presents the criteria's and sub-criteria's considered in this study.

In order to analyze the data, the multi-criteria hierarchical analysis (AHP-MCDM) approach has been used. The computer analysis steps have been implemented in Excel 2019 and ExpertChoise software.

5. Results and Discussions

The present project is an infrastructure project in the field of road construction in the region, which has faced significant delays in the project. In this regard, in the first stage, using the research literature and resources of the Ministry of Roads, various criteria affecting the delay in the construction of road construction projects will be extracted, and then during the second stage, using hierarchical decision-making methods, Prioritization of effective factors in creating delays in the road project will be done and the effectiveness of each factor will be estimated in the field and under the supervision of experts. From the point of view of the statistical population and the sample population, the present analysis has been prepared based on the evaluation of workshop and operational projects of the road construction project for the Tabriz-Bonab belt located in East Azarbaijan province.

According to the results of this stage of the study, 6 main criteria including human, environmental, management, technical and infrastructure factors and also technical errors have been identified. Each of these factors can be divided into different sub-factors, which are presented in Table 1. Each of these criteria and sub-criteria has a characteristic weight that is specified during the MCDM approach. Using the AHP approach and the MCDM system, all nodes at the n^{th} sub-criterion level are paired with n + 1 nodes. This comparison is based on the spectrum of analysis in the main criteria that has been prepared at 6 levels of management and development, which has been evaluated with equal importance and high sensitivity.

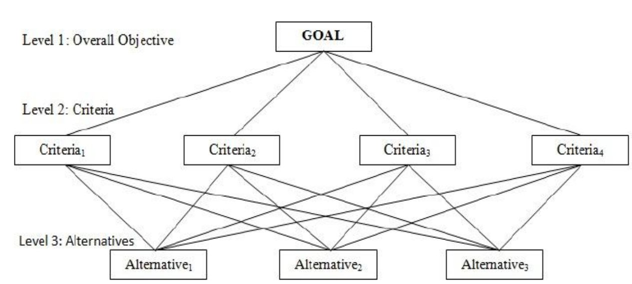

Figure 1. Structure of process architecture in AHP analysis (Greco et al., 2016)

Table 1 Criteria and sub-criteria used in this study

No.	Criteria	Sub-criteria
1	Human factors (C1)	Specialized force (M1)
		Experimental force (M2)
		Human Resources (M3)
2	Environmental factors (C2)	Topographic conditions (M4)
		Geological conditions (M5)
		Geological hazards (M6)
		Loan Resources (M7)
3	Management factors (C3)	Mismanagement (M8)
		Executive Capability (M9)
		Assignment of operating force (M10)
		Qualifications of Consultants and Contractors (M11)
		Legal issues of projects (M12)
		Specialization (M13)
4	Technical errors (C4)	One-step over-focus (M14)
		Improper use of instructions (M15)
		Lack of personnel specialization (M16)
		Lack of safety equipment (M17)
		Human error (M18)
		Special Events (M19)
5	Technical factors (C5)	Lack of funding (M20)
		Failure to resolve opposition (M21)
		Disproportion of technical-specialized ability (M22)
		Lack of design strategy (M23)
		Unexpected changes (M24)
		Employer-Contractor-Consultant Weakness (M25)
		Program Weakness and Planning Quality (M26)
		Incorrect EPM method (M27)
6	Infrastructure factors (C6)	Delay in submission of results (M28)
		Delay in transportation (M29)
		Delay in evaluation (M30)
		Lack of equipment (M31)
		Office-Workshop Bureaucracy (M32)

Equal importance means equal importance for all major criteria and high sensitivity, the degree of focus in the analysis to achieve the highest accuracy and minimum computational error. The results of these comparisons are entered in the pairwise comparison matrix and the adaptation-incompatibility coefficients are estimated to fit the opinions of the experts. The results of this process are continuously implemented for each node at one level and depending on the levels for the other nodes, and the general results of the analysis are obtained.

The estimated coefficients of the expert system are then considered as weighted score coefficients for each of the characteristics. This leads to the orientation of the AHP analysis in relation to the spatial importance of each project in relation to the scale of the whole project. For this purpose, in the present study, by presenting all the criteria and sub-criteria in the proposed model, the degree of effectiveness of each of these indicators has been determined. Figs. 2 to 8 and Tables 2 to 8 show the results of multi-criteria hierarchical analysis, along with the compatibility rate of decision matrices for each stages of hierarchical analysis. As it is clear from the results of this study, in the standard analysis, the decision matrix with a compatibility rate of 0.4% was able to prioritize the evaluation criteria. Based on the results of this optimized decision matrix, managerial factors as well as infrastructure factors have the greatest impact on the delay of the Tabriz-Bonab freeway road construction project and environmental factors have the least impact on the project. Considering this issue, it can be said that the issue of project management, the existence of administrative bureaucracies, lobbying and mismanagement are the main obstacles in allocating the freeway budget. Improper management has caused the project to be significantly delayed and eventually suspended. Therefore, by creating a proper management system and also preparing the principles of the project implementation infrastructure can be significantly pursued and put into operation in the shortest time. On the other hand, environmental factors indicate the appropriateness of the conditions in terms of work and implementation of the route, and this will significantly reduce implementation costs.

Table 2 The final decision matrix for measuring the priority of evaluation criteria

Criteria	C1	C2	C3	C4	C5	C6
C1	1	5.00	0.50	0.50	2.00	0.33
C2	0.20	1	0.11	0.33	0.50	0.14
C3	2.00	9.00	1	2.00	7.00	2.00
C4	2.00	3.00	0.50	1	5.00	1.00
C5	0.50	2.00	0.14	0.20	1	0.12
C6	3.00	7.00	0.50	1.00	8.00	1
Comparisons number		15	Delta factor			
Compatibility rate		0.04	Eigen factor		6.249	

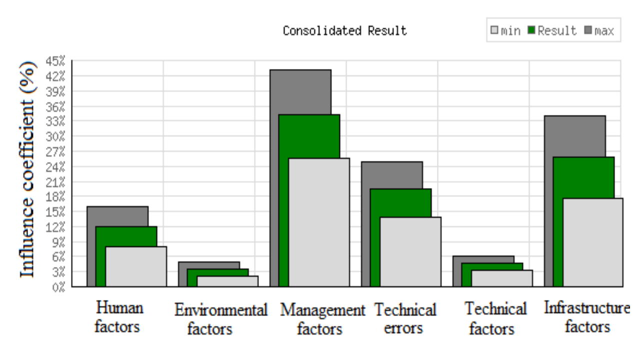

Figure 2. Chart of main criteria variation in the final decision matrix

Table 3 Sub-criteria decision matrix of human factors for measuring sub-criteria priority

Sub-criteria	M1	M2	M3
M1	1	2.00	0.33
M2	0.50	1	0.14
M3	3.00	7.00	1
Comparisons number	3	Delta factor	7.1×10^{-8}
Compatibility rate	0.03	Eigen factor	3.003

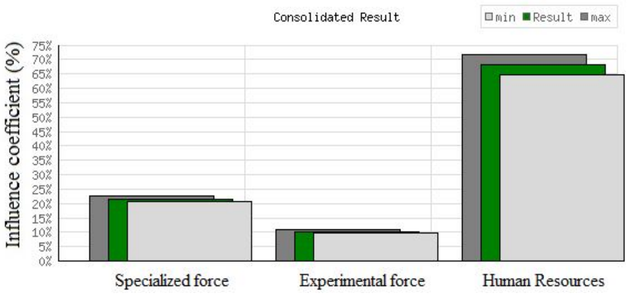

Figure 3. Chart of human factors sub-criteria variation in the decision matrix

Table 4 Sub-criteria decision matrix of environmental factors for measuring sub-criteria priority

Sub-criteria	M4	M5	M6	M7
M4	1	9.00	5.00	6.00
M5	0.11	1	0.25	0.33
M6	0.20	4.00	1	1.00
M7	0.17	3.00	1.00	1
Comparisons number		6	Delta factor	9.1×10^{-9}
Compatibility rate		0.029	Eigen factor	4.078

Table 5 Sub-criteria decision matrix of management factors for measuring sub-criteria priority

Sub-criteria	M8	M9	M10	M11	M12	M13
M8	1	7.00	7.00	8.00	9.00	2.00
M9	0.14	1	2.00	0.50	5.00	0.14
M10	0.14	0.50	1	0.25	2.00	0.20
M11	0.12	2.00	4.00	1	6.00	0.20
M12	0.11	0.20	0.50	0.17	1	0.14
M13	0.50	7.00	5.00	5.00	7.00	1
Comparisons number			15	Delta factor		2.7×10^{-8}
Compatibility rate			0.08	Eigen factor		6.500

Table 6 Sub-criteria decision matrix of technical errors for measuring sub-criteria priority

Sub	M14	M15	M16	M17	M19	M19	M20	M21
M14	1	7.00	1.00	0.25	6.00	0.17	1.00	2.00
M15	0.14	1	0.17	0.14	1.00	0.12	0.33	0.14
M16	1.00	6.00	1	0.50	5.00	0.17	0.33	1.00
M17	4.00	4.00	2.00	1	6.00	1.00	5.00	4.00
M18	0.17	1.00	0.20	0.17	1	0.12	0.20	0.17
M19	6.00	8.00	6.00	1.00	8.00	1	5.00	3.00
M20	1.00	3.00	3.00	0.20	5.00	0.20	1	2.00
M21	0.50	7.00	1.00	0.25	6.00	0.33	0.50	1
Comparisons number			28		Delta factor			2.7×10^{-8}
Compatibility rate			0.078		Eigen factor			8.765

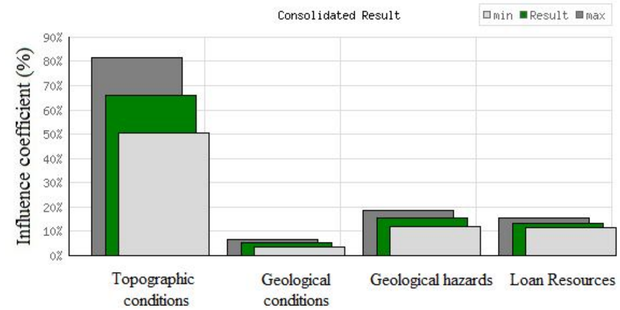

Figure 4. Chart of environmental factors sub-criteria variation in the decision matrix

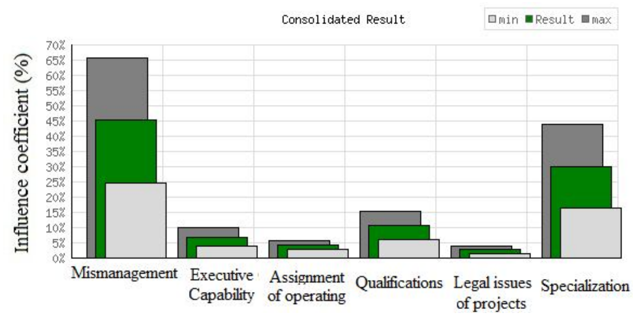

Figure 5. Chart of management factors sub-criteria variation in the decision matrix

Table 7 Sub-criteria decision matrix of technical factors for measuring sub-criteria priority

Sub	M22	M23	M24	M25	M26	M27
M22	1	6.00	0.25	4.00	6.00	1.00
M23	0.11	1	0.14	1.00	0.14	6.00
M24	0.17	3.00	1	2.00	0.17	3.00
M25	0.13	2.00	0.11	1	0.11	1.00
M26	6.00	0.20	0.17	1.00	1	0.25
M27	1.00	0.25	3.00	0.33	0.14	1
Comparisons number			28	Delta factor		4.1×10^{-8}
Compatibility rate			0.056	Eigen factor		3.363

Table 8 Sub-criteria decision matrix of infrastructure factors for measuring sub-criteria priority

Sub-criteria	M28	M29	M30	M31	M32
M28	1	5.00	4.00	7.00	0.50
M29	0.20	1	0.50	5.00	0.25
M30	0.25	2.00	1	3.00	0.20
M31	0.14	0.20	0.33	1	0.11
M32	2.00	4.00	0.50	0.25	1
Comparisons number		10	Delta factor		9.7×10^{-8}
Compatibility rate		0.06	Eigen factor		5.270

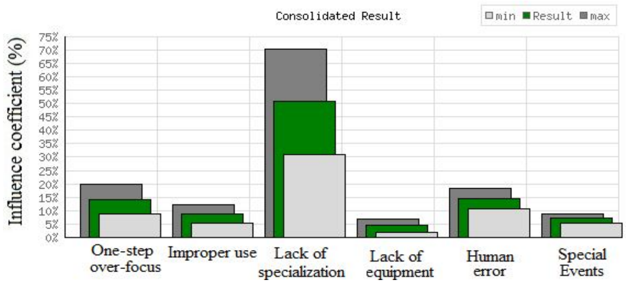

Figure 6. Chart of technical errors sub-criteria variation in the decision matrix

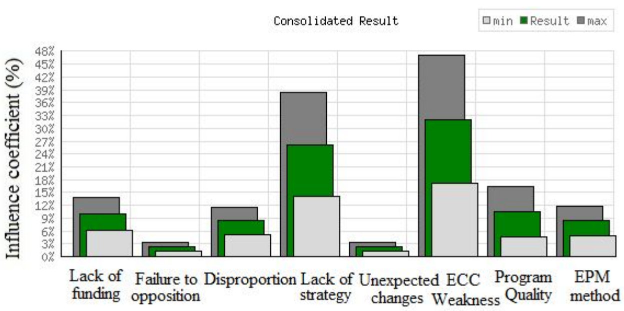

Figure 7. Chart of technical factors sub-criteria variation in the decision matrix

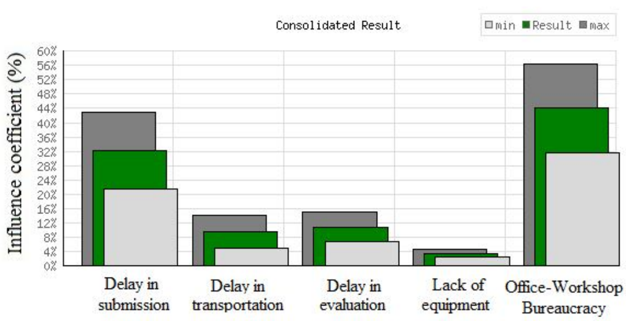

Figure 8. Chart of infrastructure factors sub-criteria variation in the decision matrix

Considering the results of the hierarchical analysis presented to measure the delay in the Tabriz-Bonab freeway project, it can be said that the project management issue as the most important factor with an impact factor of 34.3% is the most delayed factor in This factor ranking is the role of mismanagement with an impact factor of 45.3%. This shows the importance of proper management of the road construction project, which unfortunately shows the role of managerial rents. By removing this obstacle, it can be said that the project has reached the implementation stage with high speed and capability and it will be possible to exploit it. On the other hand, the role of low environmental factors has made it possible to access loan sources, avoid unfavorable geological conditions and also avoid sensitive geological hazards. This will be in line with reducing project implementation costs. In the second place are infrastructure factors that show a significant impact of infrastructure on the operation of the Tabriz-Bonab freeway project. Relying on these two operating criteria, the project can be implemented with high accuracy. Based on the results of the analysis of this dissertation, it can be stated that the role of each factor has been feasible depending on the extent of its impact on the road construction project, but in the meantime, the role of management has received a lot of attention.

6. Conclusion

Project engineering management (EPM) is considered as one of the most effective project evaluation approaches that is used to identify problems and issues involved in engineering projects and provide the most appropriate project management method. In general, EPM is a systematic method for identifying problems and issues involved in construction projects that uses to identify, analyze and prioritize the project management method of project failures and successes. One of the capabilities of EPM is the multi-factorial evaluation of the factors involved in projects, which enables the presentation of optimal multilateral decisions. One of the approaches proposed in the EPM method is the use of multivariate hierarchical analysis or AHP-MCDM. In this regard, the present study has tried to consider the relationship between the factors affecting the project construction and the time delay of Tabriz-Bonab road project. For this purpose, the multi-criteria hierarchical analysis (AHP-MCDM) method has been used to prioritize and measure the effective factors in the project. Based on the evaluations, 6 main factors including human, environmental, managerial, technical, infrastructure and technical errors were involved in the project, each of which can be divided into several sub-factors which managerial as well as infrastructure factors have the greatest impact on the project delay and environmental factors have the least impact on the project

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