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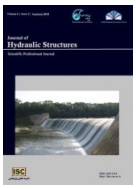

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Root Cause Analysis of Delays in Dam Construction (Case Studies: Karun-3, Marun, Shafaroud and Jamishan Dams)

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Abstract

Completion of the project in due time at the predefined quality and cost is of the most important concern. Along with the increase of duration of project implementation, the total cost of the project will be raised due to annual inflation and other introduced costs. This research has investigated and identifies the most important causes of damage occurrences and time delay, then prioritized them throughout the project cycle from the pre-construction phase up to the end of the commissioning phase. Besides, solutions to prevent these damages and resolving the challenges ahead have been developed. Thus, a list of data from literature and field surveys have been gathered. After brain storming in experts panel and collecting data; data has been analyzed through Analytical Hierarchy Process utilizing the Expert Choice 11 software, which has resulted in seven major delay factors including: deficit budget allocation (27%), economic problems of the country (24%), the weakness of contractor's site management (13%), use of not qualified personnel in construction management (11%), delay in preparing and lots of mistakes/ modifications in detail design by the consultant (10%), inaccurate proposal in tenders by the contractor (8%), and improper selection of the contractor by the client (7%). The expert panel considers that the budget allocation is the most important cause of damage to project. Finally, damage causing factors have also been classified into six effective factors as project team, client, management consultancy, engineering consultant, contractor, and uncontrollable factors such as political, economic and social factors.

Keywords: Causes of Delays, Dam, Analytical Hierarchy Process (AHP), Construction Management

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1. Introduction

The benefit of dams to mankind is unquestionable. Historical evidence points out that some of the earliest dams were constructed around 4000 years B.C.; the oldest dam of the world was built with masonry facing at Jawa in Jordan. Perhaps the oldest surviving arch dam is the one built a narrow valley on the Kebar River, around 1300 A.D., about 24 km south of the Qom city in the Mongol period in Iran [1].

In ancient times, dams were almost built for the single purpose of water supply or irrigation. Instead, nowadays with the development of civilization, dams may be built with various reasons including flood control to reduce the disaster, electricity generation as a clean energy generation, recreation, navigation improvement as well as provision of water for domestic, industrial and agricultural uses [2-5]. Also, dams are considered as a parameter of economic development, because their construction involves huge financial investments as well as large number of employments since it needs human resources [1, 6].

Dams are mostly cost effective based on their feasibility study. However, delay in completion of projects causes waste of financial and physical resources; in some cases, projects are so delayed that they have no economic justification and even do not meet the initial goals in terms of their application. It is necessary to identify the factors that lead to the stop, stagnation and slow progress of projects by reviewing the projects to prevent delays in future projects. However, due to huge number of problems and unknown factors in performing of a project, it will be impossible to have no delays in projects. Since repeated delays in projects can make additional costs for stakeholders involved in projects, it is necessary that if delay occurred, (1) determine the impact of delays with an accurate assessment, (2) calculate the losses impacts to each of stakeholders, and (3) compute the extension of the project [7].

Delays can be reduced when their causes are identified and analyzed. Since the issue of delay is common, so far, numerous studies have been carried out on the main causes, factors and their analysis in infrastructure construction projects. In a study run by Heydarieh and Kheirandish, the delays causes are prioritized as: client financial problems, contractor financial problems, obtaining permissions problems, series of order changes of the client, changes and mistakes in designs, contractor's management weakness, and inadequate experience of contractor, respectively [8].

Yates created a system to analyze delay of construction called delay analysis system. The main categories of delays are: engineering, equipment, external delays, work force, management, materials, client, subcontractors and weather conditions [9].

60 different roots of delay have been classified under four main categories: client, contractor, consultant and external factors. The results shows that the top causes behind the delays of Dam construction projects in Oman are: weather conditions, change orders, uncertainty in ground condition, poor site management, executive bureaucracy in client organization, feasibility study did not cover all aspects, mistakes in soil investigation, natural effects during construction work, difficulty of defining project requirement, slowness of decision making process, delay of obtaining approval from the different government authorities, and land acquisition [10].

Investigating the causes of delays in infrastructure projects shows that the most important cause is failure to finance the project by client; and then they can be considered as financial factors, management factors, factors related to laws and regulations and also technical and administrative factors. The causes of delays are also prioritized as follows: failure to provide on time credit by the client, inflation and unfavorable economic conditions, weakness in the country's planning and execution system, lack of proper resource planning, cost and time, and land acquisition [11].

Consideration, strengthening and modification of the role of client, consultant and contractor in the projects can have a significant impact on time managing of projects as follows: (a) client's role: weak project managers, wrong attitude of clients toward contractors, not proper and unclear tender system, lack of dispute resolution system between client and contractor, (b) consultant's role: weakness in investigating economic justification of project, and (c) contractor's role: financial, procurement and executive weakness, not proper proposal in the tender, lack of large contracting corporates, weakness of project management [12].

Eight factors have been investigated as delay causes in an infrastructure project in Iran as 1- failure to fulfill the contractor's commitments, 2- lack of providing materials properly, 3- lack of providing work force and equipment, 4- not proper contracts, 5- failure at executing client's commitments, 6- not proper communication, 7- not hiring a consultant, 8- environmental factors [13].

Babu and Meena in a study of delays in construction phase and analysis have classified the damage factors in project cycle into nine groups: project team, client, contractor, consultant and supervisor, designer, material, equipment, work force and external factors. Damage and delay causes have been categorized then as external factors, financial problems, shortage of work force, low efficiency of work force, client's interferences and incorrect planning [14].

Another study conveys the roots of delay as financial problems of client, insufficient experience of contractor, shortage of material and equipment of contractor, mistakes of detailed plan, poor site management, and weak implementation of subcontractor [15]. Also, irregular increase of use of equipment in construction projects causes delays, and likewise, maintenance plan of this equipment should be carefully considered in the project schedule. The other study shows that the most significant parameter for time is budget deficiency; for cost, errors detailed design; and for quality, faults of contractor [16].

A research in Ethiopia based on Relative Important Index and correlation coefficient declares that corruption is known as the most important cause of delay and in the next turn lack of access to utilities, inflation and price increase of material and their low quality, delay on delivery of design material as well as construction material, weak site management, budget deficiency, failure to pay financial statements on time, also the ineffective timetable of the project have increased the time and cost [17].

Marzouk and El-Rasas have analyzed the causatives of delay in construction projects in Egypt and classified the causes as (a) ten repetitive indexes including least cost selection of contractor, unfitting timetable, series of changes in programs and delay in confirmation of project documentation, and (b) effective indexes such as shortage of labor as well as construction materials in the market, cost fluctuations, on time payment failure and insufficient experience of the consultant [18].

A research has shown that the effect of organizational culture on delay in constructions differs from country to country. For instance, construction companies in America which are influenced by "family culture" has less delays than those in India, which are influenced by "market culture" [19].

By worldwide reviewing researches on the causes of delays, it is clear that the reasons for delays vary from country to country. This issue is due to cultural and social differences, type of contract, construction method, political matters, state laws, geological and weather issues, etc. [20].

The following table presents a list of studies on the causes of delay in projects.

Table 1. The classification of researches on the causes of delays in projects

Causes of delays in the construction projects	Reference
External factors, financial problems, lack of workforce, low labor efficiency, client interferences and incorrect planning	[14]
Client's financial problems, inadequate contractor experience, shortage of contractor materials and equipment, consultant design mistakes, poor site management, and poor performance of the sub-contractor.	[15]
Client's financial problems, contractor's financial problems, licensing problems, client change orders, design changes and mistakes, poor management of contractor and inadequate experience of contractor.	[8]
Delays in site selection, acquisition of land, weakness in control and review of primary studies, delays in the executing of pledged services, failure to consider the requirements of the plan of the project, lack of easy access to infrastructure facilities, failure to eliminate opponents at the right time	[7]
Change of work amount, change of executive plans, failure to meet executive prerequisites, non-fulfillment of client's commitments, coercive events, etc.	[20]
Lack of timely financing by the client, inflation and unfavorable economic conditions, weaknesses in the country's planning and execution system, budget deficits, inappropriate planning of resources and cost and time, land acquisition, weakness in contractor finances, adjustment factors not being real and	[11]
Poor contractor financial potency, administrative bureaucracy of client, lack of experience and knowledge of contractor, and the lack of experienced experts in the preparation of contracts.	[13]
The role of clients, the role of consulting engineers, the role of contractors	[12]

The main objective of this study is to identify the causes of damage and the factors causing delays in the construction phase of dam projects, review, evaluate and prioritize them from the construction management point of view.

2. Methodology

In this study, data collection has been done through field survey and literature review. Table 2 has tabulated the causes of delay and the related stakeholder whom the cause referees. All data has been obtained through library work.

Table 2. Classification of causes and factors of delays in construction projects according to literature

Row	Subject	Stakeholder	Reference
1	The technical weakness of the project team in controlling and evaluating geotechnical and topographic studies by the consultant	Project team	[15] - [18]
2	Lack of a dispute resolution reference between the client and the contractor (the lack of arbitrary judgment of the supervisory system or ...)	Client	[7] – [12]
3	Failure to choose the best suited contractor (tender system is based on least cost)	Client	[11] – [18]
4	Client's financial problems including: Failure to provide sufficient financial resources (failure to provide timely allocation of financial credits), and late payment (such as contractors, project management, and consultants)	Client	[7] – [8] – [11] - [12] – [13] – [14] – [15] – [17] – [18] - [20]
5	Lack of knowledgeable expert and experienced personnel both in technical and contractual aspects	Management Consultancy (MC)	[7]
6	Inadequate precision when carrying out geotechnical and geological studies that results in series of changes in design during construction period	Consultant	[18]
7	Not proper proposal at tender which causes problems in financial issues as well as time expansion	Contractor	[8] – [12]
…	…	…	…
32	Corruption (ethical problems of managers or site experts, bribery, applying personal styles, pertinacity and abuse of position, etc.)	Uncontrollable factors	[17]

Also, there have been series of meetings and discussions with different stakeholders in several dam projects to find out any obstacles against timely dam construction. By merging and summarizing them, a long list was extracted with 46 reasons. To prioritize the causes of identified damage and important delay factors and preparing the short list, the "Eisenhower technique in time management" method and the Pareto principle (80/20 rule) have been used. Using Eisenhower's technique, delays and damage factors are categorized in four priorities: (1) important and immediate challenges, (2) important and non-immediate challenges, (3) non-important and immediate challenges, and (4) Non-immediate and non-important ones. Then, the 80/20 rule points out that put 80 percent of time and energy focused on 20 percent of what's really important.

In this research, a panel has been established with 15 experts to use both methods to prepare the short list at the first step and fulfill the analytical hierarchy process (AHP) at the second stage. Since the composition of this panel is of the importance, the experts has been chosen among the

ones who have a solid academic background and extensive experience in dam construction in several roles such as client, consultant, contractor and MC. Table 3 shows the academic background on the expert panel and Table 4 tabulates the experience of them at a glance.

Table 3. Academic background of the expert panel

Academic background	Bachelor's degree	Master's degree	Ph.D.
Number	10	3	2

Table 4. Level of experience of the expert panel

Work experience	More than 35 years	25-35 years	20-25 years	15-20 years
Number	3	3	6	3

After series of brain storming sessions and reviewing the long list, a short list with seven alternative (delay causes) have been finalized. The golden triangle of the project describes these three indicators as time, cost, and range [20]. Since there are three criteria (time, quality and cost), a multi-criteria decision making tool is needed to prioritize the causes, so pairwise comparison throughout an analytical hierarchy process (AHP) has been chosen as an strong tool [21]. AHP can be used when decision-making comes with several choices and criteria. The proposed criteria can be quantitative and qualitative. The basis of this decision-making method lies in paired comparisons. The decision maker starts analyzing by providing a tree of decision hierarchy. At the first level, is the goal of decision making, the aim of this research is the pathology of dam projects in terms of construction management. In the second level are the indicators or criteria, and the criteria for this study include cost, time, and quality. Options are also at the third level [22]. Expert Choice software version 11 has been utilized to calculate the matrix functions and prepare the results. Figure 1 shows the conceptual model of the research according to the AHP method.

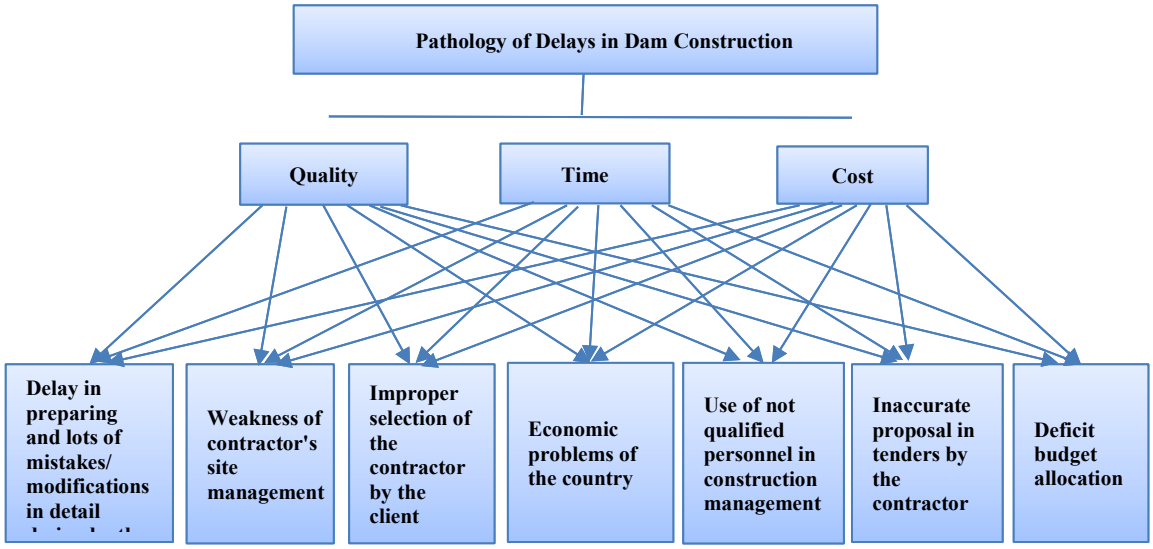

Figure 1.The conceptual model of the research according to the AHP method

After designing a questionnaire which includes the 7 short listed alternatives, each of the criteria for cost, quality and time in a pairwise comparison have been judged by the expert panel, individually. The calculation method is so that the software gives geometrical average from the points given by expert.
It is notable that 6 different delay factors affected by stakeholders of the conceptual model of this research, as shown in Figure 2, include project team commitments, client's commitments, consultant's commitments, contractor's commitments, MC's commitments and uncontrollable factors in the country's dam industry executive projects. The conceptual model has been extracted from previous studies and is a standard model [13].

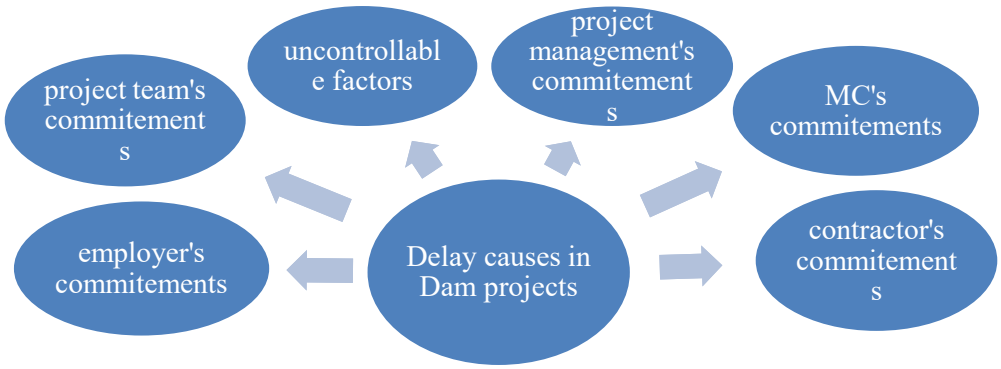

Figure 2. The six different delay factors affected by stakeholders

3. Results and Discussion

As the first results of this research, obtaining 14 parameters affecting delay in dam construction through series of meetings and discussions with different stakeholders have been summarized in a list of 14 parameters in Table 5.

Table 5. Classification of causes and factors of delays in construction projects according to field survey

Row	Subject	Stakeholder	Description
1	Not using of modern contractual framework such as: EPC, EPC, EP, Public Private Partnership, TURN-KEY, ...	Project Team	Using the traditional methods and lack of adequate knowledge
2	Not choosing the best suited contractor companies, management consultancies and engineering consultants. Failure to predict the risks that may causes delay	Project Team	Existence of informal relationships rather than formal criteria
3	Lack of on time-purchasing of equipment by the client (mechanical equipment, instrumentation and electrical equipment, etc.)	Client	Lack of proper planning as well as liquidity

Row	Subject	Stakeholder	Description
4	Lack of proper organizational structure in the client's system to meet the needs of the project	Client	Weak control over the clients by the government
5	The weakness of the project management in controlling and reviewing the detail design in the second phase of the project (including plans, tender documents, cost estimates and an accurate estimate of the duration of the project, etc.)	MC	Lack of efficient experts project management team
6	Lack of coordination with governmental authorities such as the Insurance and Social Security Administration, the Labor Office, the Engineering Organization, and the site staff to hold training classes such as safety, quality control … that reduce incidents	MC	1- Spending time and high cost on not proper training 2. Lack of sufficient knowledge and experience
7	Failure to on time cooperate of the MC to solve any problem claimed by contractor	MC	Establishment of informal relation with the client instead of technical one
8	Lack of coordination of consultant with MC and contractor	Consultant	inexperienced Supervisors
9	Failure to provide timely technical and operational solutions during construction	Consultant	Lack of technical capability of experts
10	Weakness in the machinery and equipment maintenance	Contractor	Being costly
11	Inappropriate site preparation	Contractor	Being costly
12	Improper human resources management (having qualified staff on board, commensurate payment system and meritocracy, etc.)	Contractor	Poor workshop management
13	Lack of attention to the advice of the consultant and client regarding the observance of technical specifications and the use of appropriate materials and the proper implementation of the operation	Contractor	Weak and inexperienced site management for reducing costs
14	shortage of facilities and lack of proper execution planning (in terms of labor force, climatic conditions of the region, existing project equipment in the region)	Contractor	Not checking local conditions before starting the project

By merging Table 2 and Table 5, a long list of subjects causing delay in dam construction has been obtained. Afterwards, it has been discussed through series of brain storming and long discussions in the expert panel, and a short list containing following seven most significant and effective causes of damage in the project (as alternatives in AHP analysis) has been developed:

improper selection of the contractor by the client, delay in preparing and lots of mistakes/ modifications in detail design by the consultant, deficit budget allocation, use of not qualified in construction management, economic problems of the country, inaccurate proposal in tenders by the contractor, and the weakness of contractor's site management.

Since all seven alternatives should be pairwise compared by experts against criteria such as time, quality and cost, separately; four different sets of questioners have been developed. One of them has been in terms of fining the weight of criteria. The 3 others have been developed to prioritize the alternatives against each criterion, distinctly.

All questioners have been completed by 15 experts and each has been introduced to Expert Choice 11 software as input. At first, inconsistency factor of each completed questionnaire has been calculated and investigated. Fortunately, all have been equipped with inconsistency factor of less than 10%, which shows that all of them are valid and can be used to obtain the results.
If just "cost" criterion is considered, by analyzing the related questionnaire by the software, Figure 3 is obtained. If just cost is considered, country's economic problem and deficit budget allocation of the client are the most important causes of delay in dam construction with more than 60% of weight among all 7 causes. While, delay and mistake in detail design by the consultants, hiring not qualified employees by the contractor and improper selection of contractor through a not proper tendering method by the client have about 15% of delay responsibility.

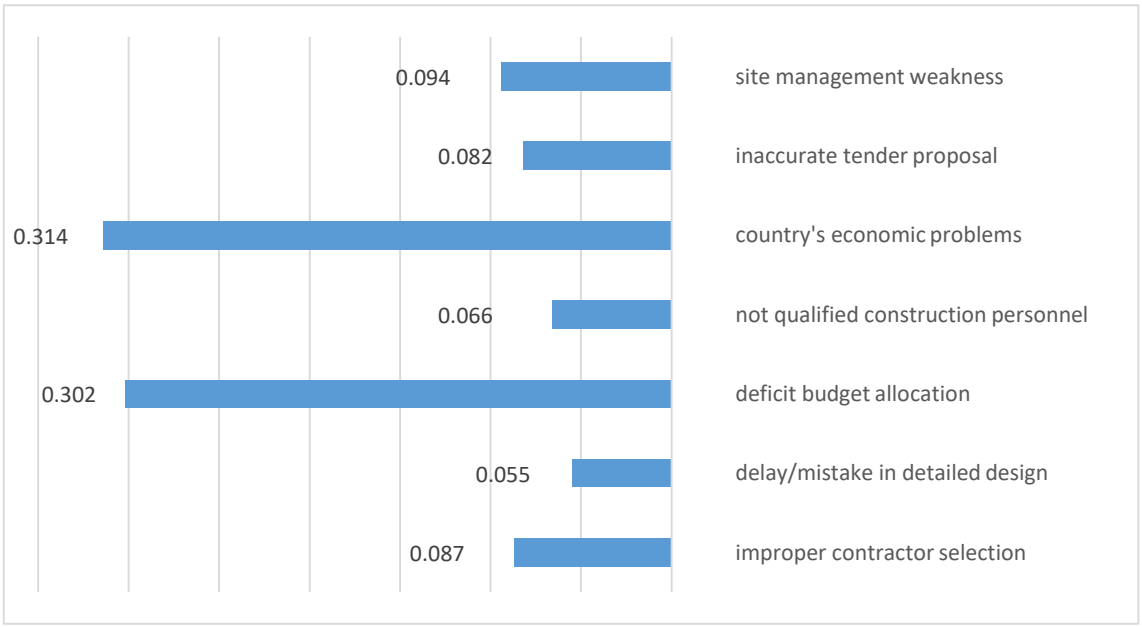

Figure 3. Importance weight of delay causes against cost criterion

As Figure 4 presents, the role of country's economic problem and deficit budget allocation of the client weights more than 60% of causes of delay in dam construction against time criterion. It is exactly the same as cost criterion. Again, the three causes which have been mentioned at above have the share of about 18% of the importance, together.

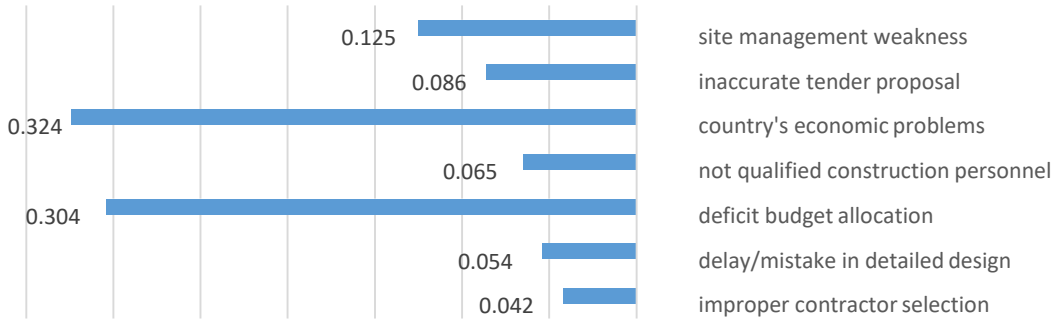

Figure 4. Importance weight of delay causes against time criterion

Criterion quality makes the order in a totally different arrangement. Site management weakness, hiring not qualified personnel by contractor and problems in detailed design by the consultant have more than 65% of share of delay roots. Instead, preparing tender proposal in an inaccurate manner by the contractor, country's economic problems and improper contractor selection have the least effect even less than 20%, totally. Deficit budgeting of the client have got 16% of importance in delay causes itself. Figure 5 illustrates the weights of short listed alternatives at a glance.

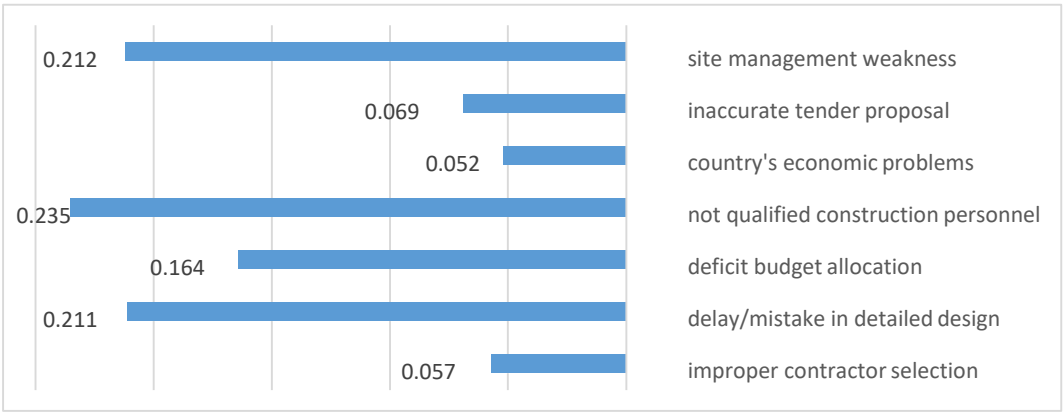

Figure 5. Importance weight of delay causes against quality criterion

As it has been mentioned before the golden triangle of project, the short listed delay causes should be analyzed against the combination of cost, quality and time, simultaneously. On this basis, weights of criteria (cost, quality and time) should be calculated. Thus, related questionnaires have been inputted to the software. As Figure 6 displays, cost is the most important criterion and ranked first, which is more than twice of the time criterion and more than two and a half times of the quality criterion in terms of importance. As a result, according to the expert panel, the cost criterion is much more important than the time and quality criteria, and the client has a major role in increasing the cost of the project with paying imperfectly at not on time. Regarding the importance of time, if the client wants to start and complete the project in due time and in accordance with the timetable approved, it should, while paying attention to the economic problems of the country, have a great deal to resolve his financial problems.

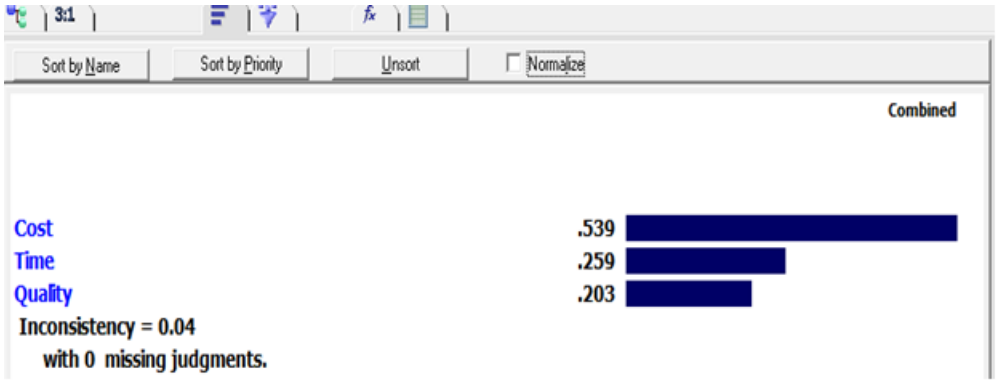

Figure 6.Priority and weight of criteria (cost, time, quality)

Since the inconsistency figure is less than 10%, the weights in Figure 6 can be utilized, safely. By multiplying each importance weight in Figures 3 to 5 by the related criteria weight, Figure 7 is obtained to provide the priorities and importance weight of delay causes against project golden triangle (cost, time and quality).

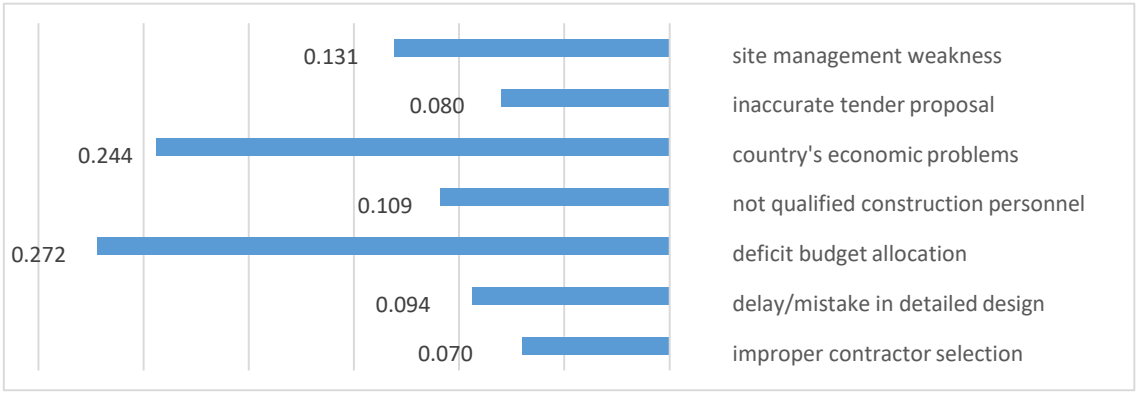

Figure 7. Importance weight of delay causes against combination of time, cost and quality criteria

As it can be observed, the financial problems of client as well as country economic troubles have more than half of total weight for the causes of delay in dam construction. The 4 other causes have almost the same weight and totally have less importance than the two abovementioned causes.

Although verification of results are mandatory for simulations, the methodology of this research is based on a multi-criteria decision making tool and the results are considered as managerial conclusion and it is not a subject to verification. Nevertheless, comparison of the results with the literature review presented in table 1 can be a scheme to certify the outcomes. As it can be seen, client's financial problems including: Failure to provide sufficient financial resources (failure to provide timely allocation of financial credits), and late payment (such as contractors, project management, and consultants) have been cited at the most rate within the literature. Accordingly, the financial problems of client as well as country economic troubles have been found out at the top priorities in this research, as well.

The other factors are cited less, the same have been happened in the analyzed weight in this research.

By analyzing the issues against the six effective factors (project team, client, MC, engineering consultant, contractor, uncontrollable factors (political, economic, social, natural factors, state laws and regulations, and opponents)), the client's factor had the highest impact and plays the most important role.

Three different sensitive analysis has been fulfilled to recognize how fluctuations in weight of criteria can affect the ranking of delay causes. At first step, if quality criterion is raised from 0.203 to 0.6, ranking will be changed and weakness of contractor in site management will be at the second rank. Should the quality weight comes at four times more (80%), hiring of not qualified personnel, deficit budget allocation and weakness of site management will be the top three delay causes, which all are among the commitments of the contractor. The least important one will be badly selection of the contractor by the client.
It can be recognized from the first sensitive analysis that if government wants to have a high quality project, a strong project team is of extraordinary significance. Then, detailed budget planning with actual time plan is needed. So, project financing and on time payment would be considered.

In the second round of sensitive analysis, time criterion weight has been increased from 0.259 to 0.6. In this case, the first two causes has been remained but in a reverse order. So country's economic problem has come to the first ranked and client budget deficit has gone to the second row. By analyzing this case, it is obvious that if the government wants to have the dam project is finished in a timely manner, paying attention to country's economy and also careful budgeting are the keys.

Finally, by augmenting the cost criterion from 0.539 even to 0.99 and also decreasing to nil, there will not be any changes in ranking of the delay causes. Accordingly, decrease or increase of cost do not affect the delay causes, thus the government should focus on financial problems both at the country level and project budget. After that, utilizing strong site management is the vital parameter.

4. Conclusion

Dam construction is a vital method to secure water supply as well as prevent the destructive effects of flood. Since dams are quite imperative projects, any delay can have irrecoverable consequences. Given the huge costs of constructing dam projects, the importance of this study is evident. Considering that the delay has been an inseparable part of the implementation of the projects, the present study identifies, evaluates and prioritizes the damage and challenges during the construction phase, in order to have on time, correct and immediate action for eliminating or reducing the significant damage from the perspective of construction management.

Seven important causes have been summarized from a long list of 46 items. Then they have been ranked and weighted against time, quality, cost and combination of them.

By exploring earlier studies in relation to the theme of this article, what distinguishes itself is a new factor called the economic problems of the country, which has grown significantly over the past year and is one of the uncontrollable factors.
In order to overcome the budget deficit of the client as the second important delay cause, so

clients must prepare a suitable program for project financing before the start of the project. Also, they should determine their strategic decision regarding project payments including implementation cost, equipment purchase, material costs, etc. On this basis selection of the contractual framework should be carefully selected because the payment method depends on the contractual framework such as lump sum, cost plus, fixed price with annual adjustments.

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