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A Framework to Predict Time and Cost Risks based on Project Factors

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Abstract

The occurrence and severity of risks are directly associated with the project factors, and in the case of determining a logical and significant correlation between project factors and risks, the final conditions of the project based on the initial and definite project factors can be predicted. In this research, a final list of 112 risks was prepared using the views of experts. Then, the risks' weight was determined based on their impact on time and cost and according to the repetition of each risk in the earlier studies, as well as the use of 630industry experts using online web-based forms. Afterwards, 21 project factors that could affect the probability of occurrence and severity of risks related to time and cost were identified, and these factors were prioritized for each risk using the views of 25 experts. Then, applying the Pareto Principle, 14 project factors were identified. In all 4cases, including calculating the weight of risks in the technical literature as well as the experts' views by time and cost, 14 selected factors were the same, but the weight and effects were different. The results indicate that considering these factors, the risks of time and cost increase from the initial estimate can be accurately predicted.

Keywords: Prediction; Time; Cost; Risk; Project Factors.

1. Introduction

The risk analysis in the early stages of a project is a time-consuming process associated with many uncertainties. Quantitative risk analysis in particular, in addition to being time-consuming and involving uncertainties, requires significant information and data that cannot be easily assembled in a project. One of the most important problems in construction projects is increase in time and cost of the projects form the initial estimates [1], so that if time and cost are known from the beginning, the approach and macro-management decisions might be different.

Risk and its management is important for the success of the project, the risk management, which encompassed of planning, identification, analysis, and response has an important phase, which is risk response and it should not be undermined, as its success going to the projects the capability to overcome the uncertainty and thus an effective tool in project risk management. Risk response used the collective information in the analysis stage and in order to take decision how to improve the possibility to complete the project within time, cost and performance. Project managers should allocate more budgets for responding the project risk when the secondary risk is considered, and consider all factors relating to both time and cost so as to select appropriate RRAs to mitigate primary risk and secondary risk [2]. Risks affect integrated risk management paper found risks concerning employees, performance, responsibilities, agreements and timing [3]. Employing an appropriate decision-making system to identify timely project risks can prevent delays.

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At the time of the contract, a construction project has a defined initial cost or initial estimate and an initial or estimated time of the contract. During the execution of the project, the risks and factors occur that lead to changes in real time and cost of the project compared to the estimates [4].

The questions raised in this research are as follows: Is there a reasonable and significant relationship between project factors and risks? Is it possible to predict the changes in time and cost of projects resulting from internal and external environmental conditions of the project based on relevant factors in the early stages of the project? What are the most important factors to predict the time and cost from the beginning of the project?

Quality, time, and cost are three main objectives of every project that a project management team seeks to achieve in the context of safety. The quality as fully defined in the regulations and standards is among the objectives, and the tolerance limit of each part of the product is also specified [5]. In management decisions, time and cost are constantly subject to decision-making for rebalancing the objectives of the project [6].

These two objectives have several characteristics, the most important of which from the point of view of this research are as follows:

1. The time and cost of the projects have no accurate and standard basis for definition. Any organization and establishment estimates the initial time and cost based on available information and data. A unique standard cannot even be defined at the national level, and thus, the initial estimated time and cost of the projects would always deal with the changes during the project.
2. Time and cost would often change to meet quality and safety standards and regulations; any problem in other objectives of the project affects one or both of these factors, and the priority of project management is to resolve the problems in other objectives of the project through rebalancing time and cost.
3. Time and cost factors are much more susceptible to risks, with more effectiveness in case of occurrence of risks. Many risks directly target time and cost.

Regarding the above characteristics, changes in time and cost or both are common in construction projects, but the strategic and project managers are inclined to predict possible changes in time and cost to make the proper decisions and policies. In some cases, if changes in time and cost can be predicted from the beginning, these changes could be possible in the strategic decisions of the project [7].

Since many risks resulted from the strategic decisions of the project, which is beyond the control of the operational managers, prediction of changes will be more useful and effective when it is done accurately in the project's early stages. For example, it should be decided which project delivery system (PDS) should have direct effects on future decisions and, consequently, on the risks of the project [4, 8].

Instead of risk analysis, if a model could be presented to predict changes in time and cost or to analyze each of the scheduling activities (which is not possible in the early stages of the project), using the information and factors that are clear at the early stages of the project, and on the other hand, the definite rather than probable parameters, it is possible to predict the changes in time and cost with an acceptable accuracy or control the variations based on changes in various initial parameters. Finally, time and cost uncertainties could be managed, and the initial parameters of the project in a strategic decision-making process could be changed until the best results are achieved [9].

There is a difference in the nature of such a model from those that estimate the cost (or time) based on the factors of repetitive projects or those models that evaluate changes in time and cost in various situations of a parameter. In this model, the initial estimate and cost are based on the input parameters. If there is a model that could predict possible changes with a proper approximation, considering the conditions of the internal and external environment of the project, the employers and decision-makers can make better plans before starting operations. According to the logic presented in Figure 1, such a model can be defined and presented; however, the required data cannot be easily obtained, and one of the reasons that no model has been presented so far at this scale and function, in addition to ambiguity in the accuracy of results, is the difficulty of collecting the required initial data.

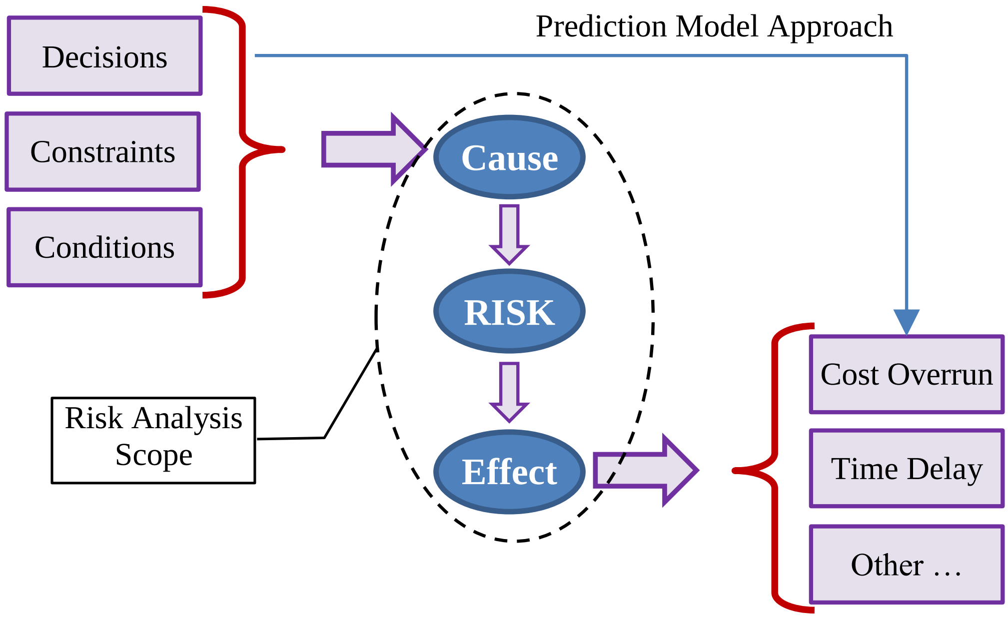

Figure 1. Risk prediction model based on project factors

2. Literature review

Risks are definite events or a series of conditions in the project or its environment leading to a lack of certainty. The purpose of identifying risks is to reveal and record the details of the largest possible number of uncertain events before their occurrence. This leads to the possibility of creating a required management space to deal with risks before their possible occurrence. In order to identify the risks, the origin of risks, real risks, and potential effects of risks should be defined [10]. Risk management is an essential component of construction projects, and its success requires participating and taking the inputs from all project stakeholders in the design and construction phases, and effective risk management entirely depends on stakeholders sharing the same understanding of the risk (s) [11].

Moreover, risk management is a dynamic process throughout the life cycle of the project because risks change in different phases and stages, and there are many interactions between the known risks, causing a lot of problems in modeling and managing the risks [12]. Hence, risk analysis is important not only to achieve a comprehensive list of risks and a full understanding of their causes, also to participate in strategic and managerial decision-making and creating more effective interactions for project success [10].

Construction projects are among the most important projects executed in every country. These projects are highly important due to their high consumption of resources [13], different stakeholders, and impacts on other sectors. Also, the construction of this project is associated with many risks due to its complexity, which requires formulating an effective risk plan. The design of a risk plan is very complicated for such projects, and despite the high cost and time, the existing methods still need to be reviewed.

The changes in the final (real) time and cost of the construction projects from the estimated initial values is a problem found in all countries and cultures, and are not unique to a region of the world or a particular culture of management and execution [1]. The changes in time and cost will be followed by many claims, and this problem is a constant part of such projects. The problem is not the existence of claims, but how serious the claims are [14]. A project in the construction industry is often considered successful if completed on time within a defined budget and is of quality. One of the main tasks of executive project managers with regard to claims is to ensure that the project is not violating the predefined cost and time frameworks [15]. Over the past two decades, a large number of professional and specialized articles worldwide have focused on the increase in time and cost. Each of these articles, which are the results of research study, has investigated the topic of an increase in time and cost. Some of them have investigated this problem in a quantitative manner [1, 16-23] while some others have taken a qualitative approach [24-31].

Hwang et al. (2017) identified and investigated risk factors in sustainable business building projects in Singapore and compared them to risk factors in similar traditional construction projects, and after the questionnaires were completed, a list of sensitive risk factors was identified in the construction process of green business buildings. The factors were evaluated and compared with the relevant factors in traditional projects, and in the end, some solutions were presented to reduce the impact of those risk factors [32].

Farnsworth et al. (2016) identified the effects of PDS - construction manager/general contractor (CM/GC) - on risks in the construction process. The employers, contractors, and design engineers with significant experience in CM/GC were investigated to identify differences in understanding of CM/GC processes [33].

The studies carried out so far on the risks in sustainable construction projects have been generally focused on the type of risks in the project and their effect on the objectives of the project. This type of study of internal perspectives emphasizes that the risks behave independently. If many of the risks are associated with project factors, many researchers have recognized that there is a certain inconsistency in understanding of risk in construction projects, which is a highly important issue, and effective risk management is based on consensus and the cooperation of all members, but achieving such integration is difficult [11].

Anastasopoulos et al. (2012) also provided an experimental evaluation of probability and severity of delay in road construction projects. They collected information from a large number of transport projects, and after completing a literature review, deciding on interview methods, and collecting the views of experts, they finally concluded that the factors of initial contract cost, initial contract time, weather conditions, and type of project are more important in determining project delay, as the other factors cannot be involved in the prediction. Additionally, another important conclusion of these researchers that was not considered in the prediction model is the significant effects of management and design decisions on project delay, so the extension projects of the contractor for cessation of rental traffic have much better performance in terms of time [20].

Vrcek et al. (2015) proposed a methodology of cost-related risks analysis in e-government projects [34]. Also, Gu et al. (2011) focused on cost analysis of design-build (DB) projects, using the hierarchical probabilistic analysis of cost for the research in the DB domain. They attempted to analyze the cost of DB projects using the structure of breakdown of work and the concept that the assigned cost for each activity is in fact a cost that is incurred [35].

Most construction projects in different countries deal with increased time or cost or both than the initial estimates. Many efforts have been made to predict the time and final cost of the projects, most of which can be summarized in three general categories. In the first category, changes in time and cost have been evaluated using analysis of risk and details in activities of a project. In the second category, time and cost have been predicted using the physical factors of a project. In this category, mostly repetitive projects such as roads, construction, tunnels, and similar items with repeated and definite elements are modeled. The input parameters of these models are usually physical factors including length, width, and diameter. For the third category, changes in time and cost have been evaluated based on specific factors of the project. For example, the time and cost changes in DB and DBB projects or small- scaled and large-scaled projects are compared with each other.

Orangi et al. (2011) evaluated the issue of delay in pipeline projects in Australia [36], and Idrus et al. (2011) presented a model for estimating the cost uncertainties in projects using risk analysis and fuzzy expert systems. In the construction projects, usually between 5-10% uncertainty is considered to estimate the project cost using the experiences of previous projects, but this method is not properly supported. There are various methods of predicting the uncertainty of cost estimation, many of which use the academic and formal principles for modeling and predicting the uncertainties, which cannot be used in the construction industry. In the present study, a flexible and practical approach is proposed to predict cost uncertainty that can be used by the construction industry [37].

Hong et al. (2011) proposed a prediction model for construction projects at the design stage for residential buildings using the CBR method. The method and results of that paper can be used in the current research, but it should be noted that the view of cost prediction in this paper is in fact a kind of cost estimation, and the risks of the construction field received no particular attention in neither internal nor external environments [38].

Lu et al. (2011) used genetic algorithm planning to predict the cost of highway construction projects. In this research, the cost-effective factors were used by programming in Visual Basic to provide a model for predicting costs of highway construction projects [39].

In fact, any change in the initial prediction is due to risk. In order to predict the final time and cost of a project using the initial estimate, a comprehensive risk analysis should be carried out, which requires considerable time and cost. Additionally, a comprehensive and complete risk analysis requires a precise recognition of the factors and characteristics of the project, internal environment, stakeholders, external environment, industrial environment, national environment, and sometimes the international environment. The occurrence and severity of risks are directly dependent on the above factors. However, the degree of dependency is different for different projects, but if there is a reasonable and significant correlation between project factors and risks, models can be provided to predict the final conditions of the projects based on the initial and definite factors of the projects.

3. Research Methodology

This research involved different stages to achieve the determined objectives, and different methods were used in each stage. Achieving the results of the research was mainly based on two methods of expert judgment and statistical analysis. In this research, it is also noted that the maximum participation of experts should be attracted using modern web-based tools for higher accuracy and reliability of the results. Figure 2 shows the stages of research methodology.

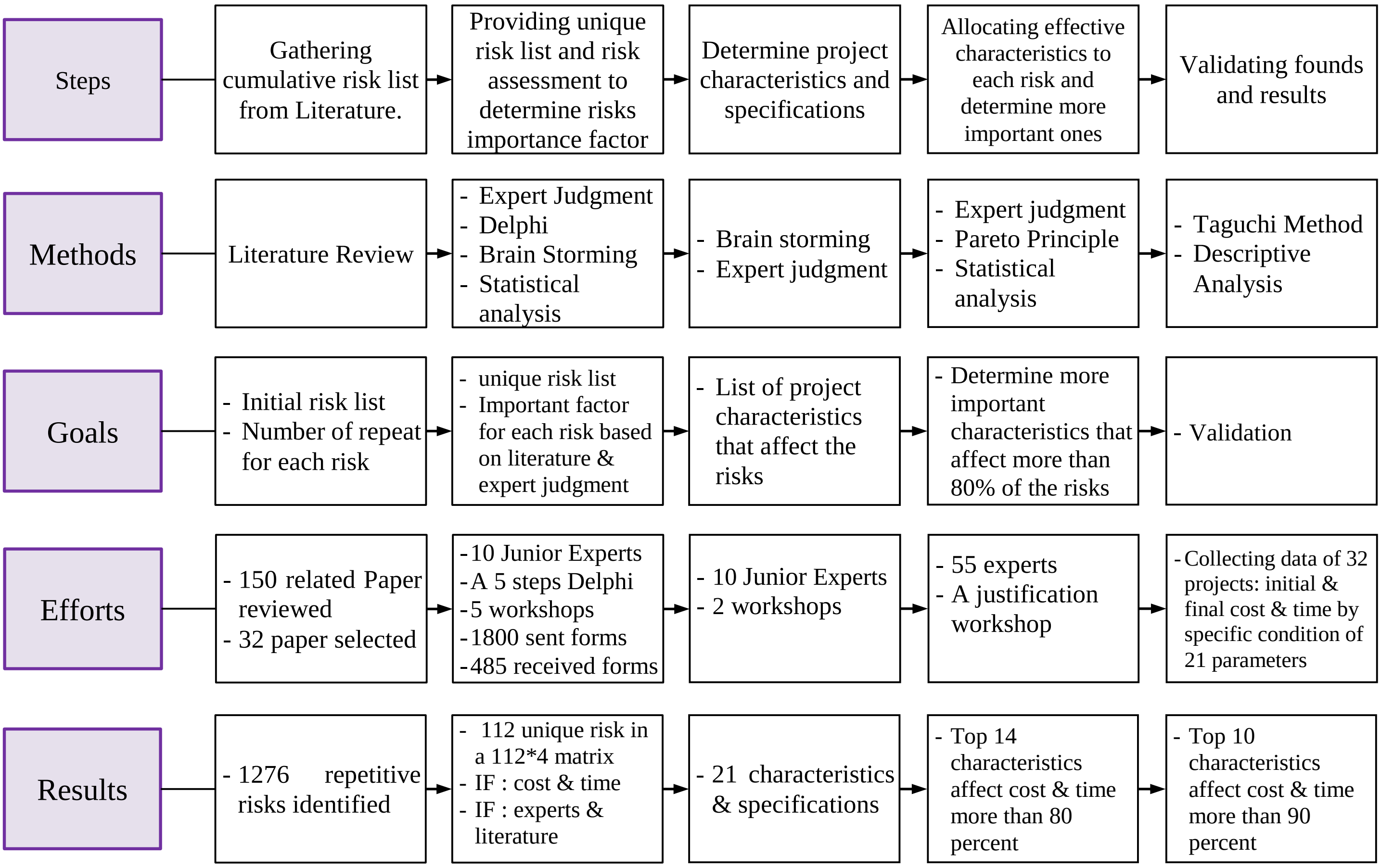

Figure 2. Final risk breakdown structure that was more suitable for the purpose of this research

3.1. Providing Cumulative Risk List

The first step is to provide an almost complete list of risks identified in previous studies and research in different countries and across various types of projects. Hence, several articles published in recent years were investigated. A list of previous studies used to identify the initial list of risks was studied [1, 4, 6, 7, 9, 15, 18, 19, 20, 25, 26, 27, 30, 31, 35, 40-56]. From these 32 papers, a total number of 1276 risks were cumulatively identified. This list has these characteristics:

1) A large number of risks were repetitive in various studies.

2) A large number of risks was addressed by different literature in various studies, but had the same concept.

3) In some of the studies, a risk was repeated across several different studies.

4) Some of the items noted in the studies as risks basically could not be risks, but rather a source or effect of risk.

3.2. Providing Unique Risk List

In order to provide a unique and complete list of risks affecting time and cost in the construction industry, 25 experts in this field with more than 20 years of experience were initially identified in various types of construction projects, including building construction, road construction, and damping. Those 25 experts were invited to attend workshops, and the subject was explained to them. Initially, it was necessary to provide a risk breakdown structure for better identification of risks. They were asked for written proposed structures, and the views of members were closer to using the Delphi method in a few rounds, and eventually the final risk breakdown structure in the workshop was as follows: (See Figure 3)

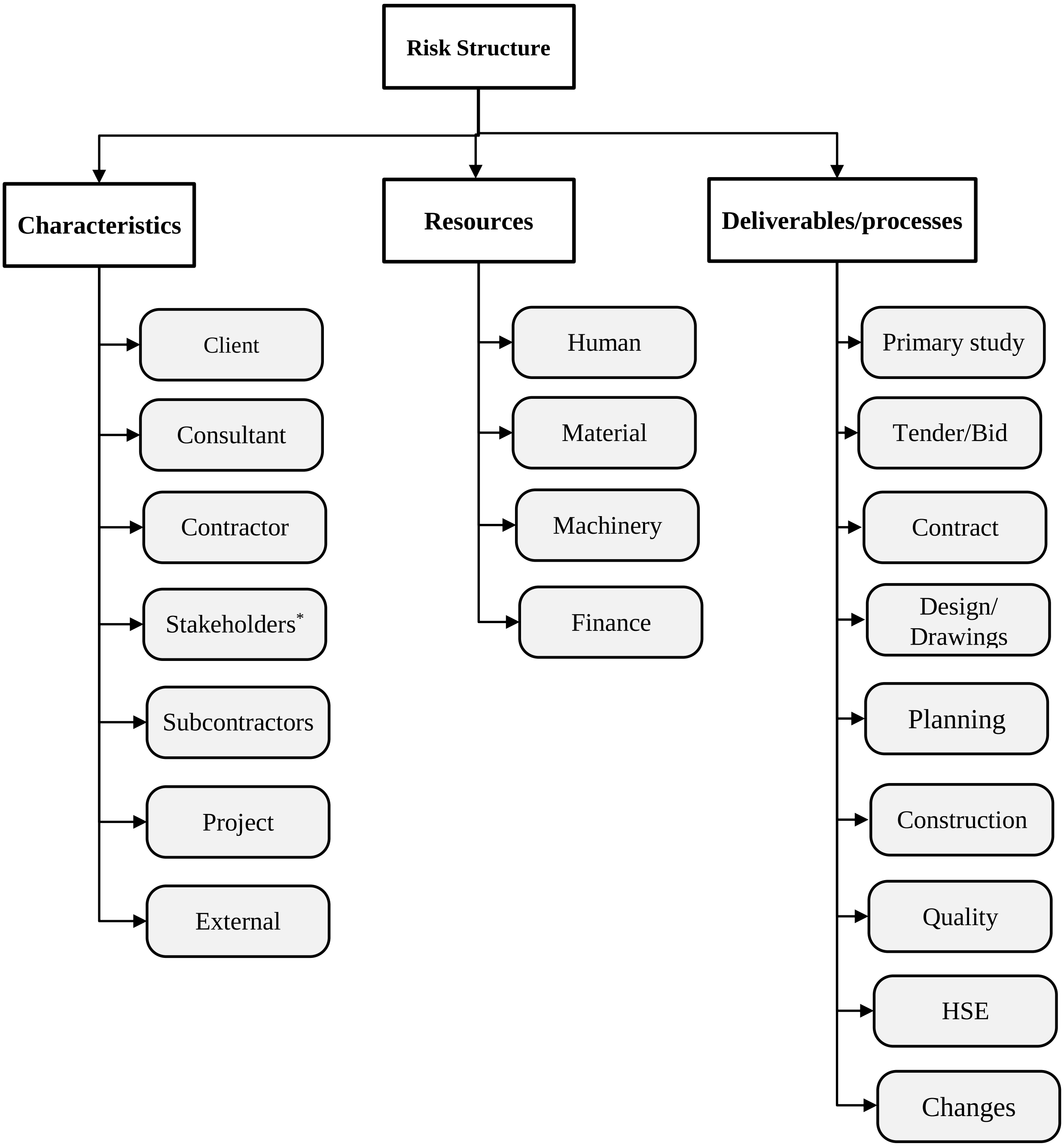

Figure 3. Final risk breakdown structure

In the next step, a list of 112 risks was prepared using the thought storm. Then, according to Table 1, 112 known unique risks were corresponded to the risk breakdown structure.

Table 1. Unique risk list corresponded to risk breakdown structure

Risk Structure			
Row	**Category**	**Title**	**Number**
1		Consultant	6
2		Client	8
3		Stakeholders	6
4	Characteristics	External	6
5		Subcontractors	4
6		Contractor	5
7		Project	2

8		Design/Drawings	6
9		Tender/Bid	3
10		Primary study	3
11		Quality	3
12	Deliverables/Processes	Contract	8
13		Changes	3
14		Planning	2
15		HSE	2
16		Construction	15
17		Material	13
18	Resources	Finance	3
19		Machinery	6
20		Human	8
Sum			112

3.3. Weighing and Ranking Risks

At this stage, four different weights for each risk were obtained.

3.3.1. Weighing Risks based on Past Studies

The analysis of importance and weight of each risk was based on its impact on time and cost in accordance with the information provided in the past studies. Finally, based on the number of risk repetitions in previous studies, the relative importance was determined using the following equations:

$$\mathrm{WRiC_L} = \frac{\mathrm{NRiC_L}}{\sum_0^{112} \mathrm{NRiC_L}} \tag{1}$$

In this formula:

WR_iC_L: The weight of i^{th} risk in the list of 112 unique risks according to the past studies based on its effect on cost.

NR_iC_L: The number of i^{th} risk repetition in the list of 112 unique risks according to the past studies based on its effect on cost.

$$\mathrm{WRiT_L} = \frac{\mathrm{NRiT_L}}{\sum_0^{112} \mathrm{NRiT_L}} \tag{2}$$

WR_iT_L: The weight of i^{th} risk in the list of 112 unique risks according to the past studies based on its effect on time.

NR_iT_L: The number of i^{th} risk repetition in the list of 112 unique risks according to the past studies based on its effect on time.

3.3.2. Weighing Risks based on the Views of Experts

In order to determine the weight of risk based on the views of experts, a unique list of 112 risks was provided along with explanations that define the concept of risk for experts in order to avoid different perceptions. Experts gave scores of 1-5 to each risk individually based on their impact on an increase in time or cost based on their previous project experience. Given the large number of questions (risks) and large number of subjects, the simple weighting method was used for filling out the scoring form and a 5-point Likert scale was used for scoring.

The form of views of experts for risk scoring was sent to 1000 experts whose information in the database included consultants, contractors, employers, investors, and other major stakeholders in the construction industry. A number of 630 completed forms were received. After collecting the forms, the average score of each risk was obtained using simple averaging, and the weight of each risk was then determined by dividing the score of each risk by the total score. At the end of this stage, two more weights were obtained for each risk:

- The weight of i^{th} risk in the list of 112 unique risks according to the views of experts based on its effect on time.
- The weight of i^{th} risk in the list of 112 unique risks according to the views of experts based on its effect on cost.

3.4. Determining Project Factors Related to Risks

The risks cause changes in time and cost of the project, and as seen in various studies, significant relationships can be found between project factors and effects of risks in different types of projects (time and cost changes). In some research [9, 55, 56, 30, 46, 51, 26], time and cost changes are dependent on project factors.

In this section of research, it was determined what factors of the project have the highest correlation with risks and thus with time and cost variations. Hence, it was necessary to prepare a list of all project factors based on previous research. Consequently, according to the views of 25 experts whose factors have been mentioned, an initial list was prepared that was filled out and corrected based on the subject literature. Eventually, using the thought storm and expert evaluation, 21 main factors of the project that might be associated with risks resulting from time and cost variations were determined according to Table 2.

Table 2. Project factors associated with risks resulting from time and cost variations

Number of Factor	Category	Project Factor
1	Employer	Employer type
2		Employer experience
3	Project Structure	Financing method
4		How to choose implementation method
5		Consultant selection method
6		Project assignment to the contractor
7		Contract pricing method
8		PDS
9	Contractor	Contractor type
10	Consultant	Consultant type
11	Project	Project size
12		Type of project 1
13		Type of project 2
14		Project location
15		Project site
16		Project components
17	Outside of Project	External pressure on the project
18		Indicator of foreign policy conditions
19		National political changes
20		Completion of peripheral information
21		National economic indicator – inflation

In the next step, it was necessary to identify the factors that had the highest effect on time and cost variations in other words, those with the highest correlation with risks. In order to provide the main factors of the project, the Pareto Principle was used, and it was decided to determine the factors that cover at least 80% of the risks and the time and cost changes.

Given that all the risks affecting time and cost were identified and ranked in the previous stage, the same results were used to determine the main factors. The list of 112 known risks affecting time and cost changes was provided to 150 construction industry experts with at least 15 years of experience in the industry. They were asked to weight the effect of that factor in terms of severity of risk in the relevant columns for each factor. Therefore, 100 units of weight were divided between different factors. It was also explained that if the factor is not effective at a risk, a score of zero is given. Since the spectrum of experts is very diverse (different types of stakeholder and project), if the weight distribution between factors is made without limitations, it was suggested to weigh 3-4 major factors for every risk in order to increase the accuracy of scoring, and the weight distribution of 100 among many factors is avoided. 55 of the 150 individuals who had been invited filled out the forms, and ultimately a total of 55 completed forms was received.

For each risk, a total of 5500 points were distributed between various factors of the project based on the percentage of effectiveness on the severity of the risk, and the weight of each factor was obtained at severity of risk of 10 by dividing the score of each factor by 55. For the final conclusion, a matrix with dimensions of 116*25 should be provided using simple statistical methods. In this matrix, the rows consisted of 112 risks, and the last 4 rows were used to insert the results of calculating the weight of each factor, and the columns consisted of 21 factors. The first 4 columns were used to insert the weight of each risk affected by time and cost based on the technical literature and views of experts (See Table 3).

Table 3. Calculating the weight of each project factor

Risk	Technical Literature		Experts' View		50	30	10
	Time	Cost	Time	Cost	Factor1	Factor2	Factor3
Change orders by employer during construction period	2.14	2.41	1.7	1.8	F20	F2	F1
Delay in payment of work statements	2	2.41	1.7	1.3	F7	F3	F9
Shortage of labors (skilled & non-skilled)	2	1.72	0.9	0.7	F8	F15	F16
Abnormal weather condition	2	1.72	0.9	0.6	F15	F12	F11
Shortage of professional, technical and managerial staff in contractor companies	1.87	2.76	1.2	1.7	F9	F8	F16
Inappropriate planning, scheduling and other project management documents	1.87	2.41	1.3	1.5	F2	F10	F8
Ambiguity, confusion, contradiction and conflict in the technical specifications and drawings	1.87	1.72	0.9	0.8	F8	F3	F2
Poor communication and flow of information between main stakeholders	1.87	1.38	1.3	0.7	F1	F9	F10
Subcontractors issues (incompetence, financial weakness, delays)	1.87	1.38	1.2	1	F9	F13	F6
Unexpected and different geotechnical, geohydrology and site soil conditions	1.74	2.76	0.8	1.3	F11	F20	F14
Applying inappropriate, wrong or obsolete technology and method	1.74	2.07	1	1	F9	F8	F6
Conflict between main stakeholders	1.74	1.72	1.3	1	F2	F1	F9
Employer delay in decision making	1.74	1.38	1.3	1.1	F1	F2	F16
Delay or failure to provide the necessary permissions from third-party organizations such as the municipality and the environmental organization	1.74	1.03	1.1	1	F15	F12	F14
Material shortage in the market	1.74	0.69	0.9	0.6	F11	F21	F14
Rework and qualitative and technical mistakes during construction	1.6	1.72	0.9	1	F6	F9	F16
Changes in national laws and technical and engineering regulations at the time of execution relative to the time of studies and design	1.6	1.38	0.9	0.8	F19	F11	F19
Short time considered in the contract	1.6	1.03	1.3	0.8	F2	F17	F8
Fluctuations and price increases for materials, wages, energy and other resources	1.47	2.07	1.1	1.9	F21	F18	F19
Delay in tests and inspections during and after construction	1.47	1.03	1.3	1.3	F9	F8	F10
Occurrence of accidents leading to death during execution	1.47	1.03	0.8	0.9	F15	F11	F9
Delay in delivery of supplies by suppliers	1.34	1.72	0.9	0.7	F7	F21	F6
Inadequate contractor experience in similar scale projects	1.34	1.38	1	1.1	F6	F1	F2
Lack of suitable machinery and equipment required for the project	1.34	1.03	1.3	1.2	F6	F9	F14
Failure and disruption of the main machinery and equipment of the project, which do not have reserve	1.34	1.03	1.3	1.2	F16	F12	F9
The contractor's delay in the provision of materials	1.2	2.07	1	1	F6	F12	F9
Difficult regulations on safety, environmental issues and traffic	1.2	1.38	0.9	1	F12	F15	F16
Inefficient and inefficient process of quality control and assurance	1.2	1.38	0.7	1	F5	F3	F8
Delay in reviewing and verifying documents provided during implementation	1.2	1.03	1.2	0.8	F1	F2	F10
Financial weakness of contractor	1.2	1.03	1.5	1.2	F6	F9	F7
Delay in equipping the workshop	1.2	1.03	1.1	0.7	F8	F6	F9
Changing the technical specifications and the type of materials used in the project by	1.2	0.69	0.8	1.2	F8	F2	F16
High administrative bureaucracy in the employer company	1.07	1.03	1.2	1	F1	F2	F19
Employer's delay in approval of studies	1.07	1.03	1.6	1	F1	F2	F16
Low labor productivity	1.07	0.69	1.1	1.2	F7	F12	F9

Cultural conflicts of labors and lack of peaceful coexistence	1.07	0.69	0.8	0.7	F2	F9	F11
Delay in land acquisition and delivery to the contractor	1.07	0.34	1.7	1.3	F12	F15	F14
Incomplete and inappropriate structure assigned to the project in the technical and managerial sectors of the main stakeholders	0.93	1.38	1.6	1.3	F1	F9	F10
Lack of financial resources of the employer	0.93	1.38	1.3	1.3	F3	F1	F1
Ambiguity and contradiction in the text of the contract	0.93	1.03	0.6	0.8	F1	F6	F2
Incomplete design during operational execution	0.93	1.03	0.9	0.8	F8	F16	F11
Delays in providing maps and technical specifications by the consultant	0.93	1.03	1.3	0.7	F5	F8	F4
Poor experience and expertise of the consultant in similar projects	0.93	0.69	1.1	1.3	F5	F10	F2
Damage to materials in the warehouse and displacements	0.93	0.69	0.7	0.6	F9	F7	F11
Ineffective delay penalties and hurricane incentives	0.93	0.34	1.1	0.7	F1	F2	F2
Lack of co-ordination and consensus in the internal consultant's collections	0.93	0.34	0.8	0.7	F5	F10	F16
Job suspension by the employer	0.93	0.34	1.4	1.2	F20	F2	F11
Inappropriate access to workshops and workplace environmental constraints	0.8	1.72	0.7	0.6	F12	F15	F11
Estimation of initial amount, less than reality	0.8	1.72	0.8	1.9	F20	F16	F7
Complexity of the project in design or implementation	0.8	1.38	1.2	1.5	F16	F12	F11
The weakness of the representative and the employer team in managing, deciding, providing information and fulfilling obligations	0.8	1.03	1.2	1.1	F1	F2	F17
Poor financial management in the workshop	0.8	1.03	0.9	0.8	F9	F6	F8
Inappropriate evaluation of the project and workshop in the tender and before construction	0.8	0.69	0.8	0.8	F6	F8	F14
Lack of sufficient skill in labor force	0.8	0.69	0.9	1.2	F12	F7	F15
Incomplete and ineffective coordination and communication, and conflict between different components of the contractor	0.8	0.69	0.7	0.7	F9	F11	F16
Delay in transportation and entry of materials to the workshop	0.8	0.69	0.6	0.6	F15	F14	F9
Delay in providing infrastructure required for equipping the workshop, such as utilities and gas	0.8	0.34	1	0.8	F2	F1	F8
Incorrect, incomplete and ambiguous definition of demands and requirements of the employer, goals and scope of the plan	0.8	0.34	0.8	0.7	F2	F3	F17
Problems related to resolving known or new conflicts with neighbors	0.8	0.34	1.3	1.2	F2	F15	F11
Low efficiency of machinery and equipment	0.8	0.34	0.7	0.8	F8	F7	F9
Lack of coordination of the employer in the internal structure as well as with the external stakeholders	0.8	0	0.8	0.7	F1	F2	F19
Changes and undesirable situation of macroeconomic indicators and economic instability	0.67	2.07	1	1.7	F21	F19	F18
The occurrence of natural disasters (flood, earthquake, storm, etc.)	0.67	1.38	0.6	0.7	F14	F15	F11
The weakness and low quality of the consultant staff	0.67	1.03	0.7	0.8	F5	F10	F8
Worker strikes, social crises and revolution	0.67	1.03	0.5	0.7	F21	F14	F15
Poor and inadequate contract management	0.67	1.03	0.8	1.1	F1	F9	F10
Inadequate initial studies and planning in the recognition phase	0.67	0.69	0.9	1.2	F17	F2	F3

Inappropriate PDS	0.67	0.69	1.3	1.7	F8	F3	F7
Contradiction and conflict with other projects in the area	0.67	0.69	0.6	0.6	F15	F11	F12
Unrelenting spirit of the consultant and resistance to changes and opinions	0.67	0.69	0.5	0.6	F8	F5	F16
Inappropriate or inadequate project control	0.67	0.69	0.9	0.8	F6	F8	F9
Non-conformity of specifications of provided materials with defined technical specifications	0.67	0.69	0.9	0.9	F7	F6	F14
Frequent change of subcontractors	0.67	0.34	0.7	0.8	F8	F6	F9
Inappropriate method of evaluation and selection of contractor and tender	0.67	0.34	1.1	1.2	F6	F17	F2
Low quality available materials	0.67	0.34	0.6	0.6	F14	F21	F18
Employer interventions in executive processes and consultancy studies	0.67	0	0.7	0.6	F17	F2	F8
Inadequate skills and expertise of machine operators	0.67	0	0.6	0.6	F12	F9	F8
Poor contract text, non-compliance with the actual situation and the standard texts	0.53	1.38	0.7	1.1	F1	F2	F7
Changes in the structure and number of employers	0.53	1.03	0.8	0.9	F1	F19	F2
Poor management of machinery and equipment procurement	0.53	0.69	0.7	1	F9	F6	F7
Inadequate experience and expertise of the employer in similar projects	0.53	0.34	0.7	0.7	F2	F16	F1
Delay in material selection due to the large variety in the market	0.53	0.34	0.7	0.5	F2	F8	F1
Failure to use up-to-date and advanced software and tools by the consultant	0.53	0.34	0.5	0.6	F5	F10	F16
Inaccessibility to proper machinery	0.53	0.34	1	0.7	F12	F15	F16
Robbery and issues at the workshop during construction	0.53	0.34	0.5	0.5	F9	F15	F14
Low quality of materials provided by the employer	0.53	0.34	0.6	0.6	F2	F21	F7
Contradiction and Conflict of Work Scheme of Subcontractors	0.53	0	0.6	0.6	F11	F15	F6
Changes in design and technical specifications during construction	0.4	1.72	0.8	1.1	F20	F8	F2
Low ability to execute performed design	0.4	1.38	0.8	0.6	F5	F8	F16
Proposing low price in bidding	0.4	1.03	0.8	1.3	F6	F9	F8
Poor documentation in the project	0.4	0.69	0.7	0.6	F8	F9	F2
Political and social conditions, especially related to the project	0.4	0.69	1	0.8	F19	F1	F18
Religious, ethnic and sectarian closures of the workforce and group absence of workers for ethnic reasons (celebrations, mornings, etc.)	0.4	0.34	0.6	0.5	F8	F9	F9
The effect of increasing and decreasing other contractor projects on current project	0.4	0.34	0.6	0.5	F9	F8	F6
Short time considered for design	0.4	0.34	0.6	0.6	F16	F2	F5
Delay in investigating and resolving contractor's claims	0.4	0	0.7	0.6	F2	F1	F8
High financial risks	0.27	1.03	0.5	0.7	F21	F7	F19
Non-adherence to professional ethics, forgery and fraud	0.27	0.69	0.5	0.5	F2	F19	F14
Changing consultant in the middle of the project	0.27	0.69	0.7	0.9	F5	F16	F2

Poor performance of contractor selection process	0.27	0.34	0.5	0.6	F2	F1	F6
The false claims of the employer in the contract and during the implementation of the project	0.27	0.34	0.6	0.8	F2	F1	F8
Change in key people in different stakeholders	0.27	0	0.6	0.6	F1	F7	F9
Lack of motivation in the workforce	0.27	0	0.5	0.5	F21	F12	F19
Administrative corruption in the employer's body	0.27	0	0.4	0.7	F1	F19	F7
Delay in payment to subcontractors	0.27	0	0.6	0.6	F9	F7	F11
The project's false feasibility and lack of technical and economic justification for the chosen option	0.27	0	0.6	0.7	F17	F7	F1
Delay in the clearance of imported goods, materials and equipment required for the project	0.27	0	0.7	0.6	F9	F2	F13
The employer's delay in providing the materials he was responsible for	0.27	0	0.5	0.5	F2	F1	F8
Changing suppliers	0.13	0.34	0.4	0.5	F8	F7	F9
False and incomplete implementation of the quality control process	0.13	0	0.6	0.6	F8	F4	F9
Contractor's delay in providing required documents	0.13	0	0.7	0.6	F9	F8	F7
Ambiguity, mistake, contradiction in bidding documents	0	0.34	0.4	0.7	F2	F5	F4
Sum of weights	100	100	100	100			

According to Equation 3, the weights of factors were calculated:

$$Y = \sum_{j=1}^{21} \mathrm{WR_i} = 100 \qquad (3)$$

W: The weight of factor out of 100 (50-30-10)

R_i: The risk which was effective on i^{th} factor

For example:

The weight of factor "employer experience" in accordance with cost:

$$C = Y \times WRiCL = 0.5(1.5 + 1 + 0.8 + 0.7 + 0.8 + 0.7 + 1.2 + 0.7 + 0.5 + 0.6 + 0.6 + 0.5 + 0.6 + 0.8 + 0.5 + 0.7) + 0.3\,(1.8 + 1.1 + 0.8 + 1.2 + 1 + 1 + 0.7 + 1.2 + 1.1 + 0.7 + 1.2 + 0.6 + 1.1 + 0.6 + 0.6) + 0.1\,(0.8 + 1.1 + 0.8 + 1.3 + 0.7 + 1.2 + 0.9 + 1.1 + 0.6 + 0.9) = 11.48.$$

The weight of factor "employer experience" in accordance with time:

$$T = Y \times WRiTL = 0.5(1.3 + 1.3 + 1.3 + 0.8 + 1 + 0.8 + 1.3v0.7 + 0.70.6 + 0.7 + 0.5 + 0.5 + 0.6 + 0.5 + 0.4) + 0.3(1.7 + 1.3 + 1.2 + 0.8 + 1.2 + 1.6 + 1.1 + 1.4 + 1.2 + 0.8 + 0.9 + 0.7 + 0.7 + 0.6 + 0.7+) + 0.1\,(0.9 + 1 + 0.6 + 1.1 + 1.1 + 1.1 + 0.8 + 0.8 + 0.7 + 0.7) = 12.20$$

In each of the matrix houses, the sum of the scores given by the experts to every factor in each risk was written (See Table 4).

Table 4. The weight of each factor based on the view of experts

Number of Factor	Project Factor	Condition 1	Condition 2	Technical literature		Experts' view	
				Time	Cost	Time	Cost
F1	Employer type	Public	Private	9.17	8.86	10.47	9.56
F2	Employer experience	Experienced	Unskillful	11.03	9.31	12.20	11.48
F3	Financing method	Organization commitment	Project commitment	2.95	3.21	3.25	3.44
F4	How to choose implementation method	By Study	No study	0.13	0.14	0.35	0.32
F5	Consultant selection method	QCBS	QBS	3.18	3.79	3.63	3.73

F6	Project assignment to the contractor	Negotiation	Bidding	6.66	7.03	6.63	6.72
F7	Contract pricing method	Unique price	Lump sum	3.67	3.79	3.67	3.61
F8	PDS	DBB	DB	9.31	9.31	9.08	9.01
F9	Contractor type	Completely project-oriented	Others	10.36	9.90	9.95	9.65
F10	Consultant type	Public	Private	2.10	2.03	1.95	1.99
F11	Project size	Large	Small	4.29	3.79	2.94	2.95
F12	Type of project 1	New	Developed	5.13	4.69	5.10	4.86
F13	Type of project 2	Infrastructure	Building	0.59	0.41	0.44	0.36
F14	Project location	Developed	Under developed	2.10	2.21	1.80	1.87
F15	Project site	Urban area	Out of city	5.93	5.03	4.60	4.21
F16	Project components	Complicated	Simple	3.48	3.97	3.70	4.09
F17	External pressure on the project	Political	Non-political	1.64	0.90	2.00	1.98
F18	Indicator of foreign policy conditions	Good	Bad	0.61	0.93	0.60	0.87
F19	National political changes	Stable	In transition	1.91	2.59	2.18	2.41
F20	Completion of peripheral information	Complete	Incomplete	2.66	3.93	2.62	3.34
F21	National economic indicator – inflation	Good	Bad	2.95	4.03	2.72	3.48

Therefore, 3-8 factors with different weights were identified for each risk. These factors were sorted in descending order, and weight of each factor in each risk was obtained based on the weight percentage assigned to each risk. Since the different weight of the first to third factors at each risk made the matrix calculations complicated, the average weight of the first to third factors was calculated in the matrix. Finally, weights of 30, 50 and 10 were determined for the percentage of effectiveness of these factors on the risks. To determine the weight of columns1, 2, and 3 in the final matrix, the average weight given to each column by the experts was used.

According to the results of Table 5, 14 of the above-mentioned factors are responsible for 80% of the risks affecting the time and cost of the project. Accordingly, it is not necessary to check a wide range of risks in a project, but in case of the risks associated with these 14 factors, it can be said that 80% of the risks can be identified, and in accordance with Table 5, the risks associated with these 14 factors and their effects on time and cost are determined by the views of experts and earlier studies.

Table 5. Determining 14 most important factors affecting time and cost

Number of Factor	Project Factor	Condition 1	Condition 2	Technical literature		Experts' view	
				Time	Cost	Time	Cost
F9	Contractor type	Completely project-oriented	Others	10.36	9.90	9.95	9.65
F8	PDS	DBB	DB	9.31	9.31	9.08	9.01
F2	Employer experience	Experienced	Unskillful	11.03	9.31	12.20	11.48
F1	Employer type	Public	Private	9.17	8.86	10.47	9.56
F6	Project assignment to the contractor	Negotiation	Bidding	6.66	7.03	6.63	6.72
F15	Project site	Urban area	Out of city	5.93	5.03	4.60	4.21
F12	Type of project 1	New	Developed	5.13	4.69	5.10	4.86
F21	National economic indicator – inflation	Good	Bad	2.95	4.03	2.72	3.48
16	Project components	Complicated	Simple	3.48	3.97	3.70	4.09
F20	Completion of peripheral information	Complete	Incomplete	2.66	3.93	2.62	3.34
F11	Project size	Large	Small	4.29	3.79	2.94	2.95

F7	Contract pricing method	Unique price	Lump sum	3.67	3.79	3.67	3.61
F5	Consultant selection method	QCBS	QBS	3.18	3.79	3.63	3.73
F3	Financing method	Organization commitment	Project commitment	2.95	3.21	3.25	3.44

The identified factors can be divided into external and internal categories. Some research has been performed to predict time and cost changes based on some of these external and internal environment indexes [18, 19, 23]. The internal environmental conditions of the project refer to factors such as the characteristics of the employer, consultants, contractors, PDS, contract pricing method, payment method, external financing methods, site of project, and project team. The external environmental conditions refer to factors such as economic and political conditions of the project execution site, cultural conditions of manpower involved in the project, global economy conditions, relations of the country of project execution with countries supplying materials and machinery, and occurrence of revolutions and strikes at the time of project execution. Among 14 factors identified in this study, 13 are related to the internal factors of the project. Accordingly, it can be said that the main source of risk in construction projects are the internal project factors.

4. Analysis

In this research, using a review of 32 prior studies, 1276 identified risks were extracted. Then, using the views of 25 construction industry experts, a unique and non-repetitive list of risks was prepared (112 risks) by mixing the Delphi and thought storm methods. Using the frequency analysis of repetitions for each risk in the technical literature, the ranking and risk weight was determined. Using the web-based online form, almost 1000 industry activists were asked to comment on the effect of each risk on time and cost variations, of which 630 activists completed the web-based form. The ranking and percentage of effect of each risk on time and cost changes were identified separately with analysis of the comments. In the next step, using the views of 25 construction industry experts, a set of project factors that could be effective in the possibility of occurrence or severity of time and cost risks contained 21 factors. In the next step, using the views of 25 construction industry experts with over 20 years of experience, the effective factors on occurrence or severity of the same risks were prioritized for each risk.

Analyzing the views of 25 experts and assuming that 100% of time and cost changes are due to the same 112 risks, and by slightly simplifying the analysis of forms and using the Pareto Principle, a set of 14 project factors were identified whose composition determined 80% of the time and cost variations. This analysis was performed twice, first with a risk weight in the technical literature, and second with a risk weight resulting from views of experts on time and cost, and in all 4 cases, 14 selected factors were the same with different weights and effects. As a result, in this research, the factors of the project, internal environment conditions, external environment conditions, and stakeholders that could accurately predict the increase in time and cost to the initial estimate in case of being used in the prediction models were identified and proposed. Below, 6 of the 14 factors obtained in this research are examined.

4.1. Employer Experience

Sufficient experience in predicting time and cost changes by employers, who are in fact suppliers of the project funds, leads to timely provision of financial funds and exposure to minimum legal charge due to changes while being aware of future conditions. The awareness of changes for employers might also lead to strategic decisions for variations in the contract main factors, demands of the employer, and project functions. According to the results shown in Table 5, employer experience in theory is also one of the most important factors in the risk of construction projects. This factor is the first-ranked factor in view of experts both in time (12.20) and cost (11.48), and in the technical literature, this factor is the first-ranked factor at time (11.03) and second-ranked factor at cost (9.31). If the employer has accurate information as to the final time and cost of the project before making decisions regarding beginning a project and budget, very different strategic decisions can be made.

4.2. Contractor Type

The type of contractor is proposed as the main indicator of the causes of delay (RNC) with the highest effect on timing performance. This factor directly affects programming and timing performance [24] in various ways based on the authority and limits of the contractor's responsibility [57, 23]. In this research, in accordance with experts' view, this factor obtained second rank in cost (9.65) and third rank in time (9.95) while based on technical literature it was ranked second in time (10.36) and first in cost (9.9).

4.3. Employer Type

In many cases, the employer type factor had greater effects on time and cost than project factors such as execution changes or problems [29]. The employer type factor and its relevant changes can play a key role in the success of risk identification, and the risk plan is based on employer type. For example, the type of risk planning for a project with a private employer is entirely different from that for a government employer. This factor, from the perspective of experts was ranked second in time (10.47) and third in cost (9.56) whereas, based on technical literature, it was fourth-ranked in both time (9.17) and cost (8.86).

4.4. Project Delivery Systems (PDS)

The contractual structure selection method has a significant effect on time and cost of execution, and can be a major factor in predicting the real time and cost of the construction based on risks and uncertainties. The results of 93 projects in Australia show that there is a correlation between real time and cost of construction and contractual factors [23]. According to results of this paper, based on the weight obtained from technical literature, time has the third place (9.31) and cost has second one (9.31) while both time (9.08) and cost (9.01) were fourth-ranked from the view of experts. This indicates the same significance of this factor for time and cost.

4.5. Project Assignment to the Contractor

The project assignment to the contractor can cover a wide range of assignments through restricted tender to public tender [58] and is one of the main factors in creating a practical risk plan [29]. Experts determined this factor is fifth-ranked in time (6.63) and fifth-ranked in cost (6.72) whereas it is fifth-ranked in both time (6.66) and cost (7.03), based on technical literature. Given the rankings, it can be concluded that the highest similarity in rank is between the technical literature and the views of experts for this factor.

4.6. Type of Project 1

Due to the fact that a project is started from the beginning or is a continuation of another project or development of the present project, the corresponding risk will be different [59]. Based on technical literature, this factor has the same ranking, being seventh-ranked in both time (5.13) and cost (4.69) while it, based on experts' opinion, is sixth-ranked in time (5.1) and cost (4.86). This indicates that there is a convergence in the technical literature on the same importance of this factor in time and cost. The experts also believe in the equal effect of this factor on time and cost, but they assign this factor a higher position in terms of the effect.

5. Conclusion

Identifying the risks of a project takes considerable time and cost. On the other hand, a comprehensive and complete risk analysis requires an accurate understanding of the factors and characteristics of the project. The occurrence and severity of the risks are directly associated with the above factors. The degree of dependency varies for different projects, but the results of this research show that there is a reasonable and significant correlation between project factors and risks. If models could be presented to predict the final conditions of the projects based on initial and known factors of the projects, those models can be used to achieve more accurate results in less time and at lower cost. Hence, in this research, the initial factors of the project and relevant risks are focused upon.

The results of this research show that 14 main factors in each construction project are responsible for 80% of the risks. Accordingly, paying attention to the risks associated with these 14 factors in each project and designing a risk plan on that basis leads to a decrease in complexity and risk identification and also an increase in risk management effectiveness. The results of this paper show that it is possible to identify and manage project risks from the beginning based on the project factors.

6. Conflicts of Interest

The authors declare no conflict of interest.

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