Int. J. Nonlinear Anal. Appl.
Volume 11 Special Issue, Winter and Spring 2020 , 31-52
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2020.4486

Development of a Risk Management Model for Water and Sewage Projects Using Interpretive Structural Modeling

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(Communicated by Madjid Eshaghi Gordji)

Abstract

The success or failure of a project in achieving predefined objectives is largely dependent on the suitability of its execution system. An important decision in the early stages of a project is to investigate different possible ways for executing projects and selecting the best one. This requires the identification of risk taking of projects. Risk is, in fact, the same as uncertainty and a multidimensional concept affecting the project's objectives. Risk management is defined as the risk identification and assessment process and application of specific methods to reduce risks to an acceptable level. Therefore, the initial objective of project risk management is risk identification, evaluation and control for the success of projects.
The risk management standard published by the Project Management Institute (PMI), entitled Project Management Body of Knowledge (PMBOK) was used in this study as the basic method for describing risk management. The general objective of this study was to develop a risk management model for water and sewage projects using Interpretive Structural Modeling (ISM).
The statistical population included all experts involved in the field of water and sewage projects. The Delphi method was used for risk identification. Eventually, data was analyzed with the help of the ISM and driving power-dependence power diagram (MICMAC).
According to the results, allocation of Islamic Treasury documents and bills, imprecise conduction of preliminary studies, the lack of coordination between project designers, irrelevant maps and details,

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Received: February 2020 *Revised:* May 2020

imprecise initial project estimation, the lack of adequate maps and details and project failure and its conversion into some small projects with a high level of impact-dependence are highly prioritized risks needed to be controlled.

Keywords: Risk, Risk management, Water and sewage projects, ISM.

1. Introduction

The success or failure of a project in achieving predefined objectives is largely dependent on the suitability of its execution system. An important decision in the early steps of a project is to investigate different possible ways for executing projects and selecting the best one. This requires the identification of risk taking of projects. Risk is, in fact, a measurable uncertainty, but uncertainty is an unmeasurable risk. Risk, itself, is a multidimensional concept [1] defined as the probability of a harmful event in a project affecting the project's objectives [2]. Nevertheless, this concept is not always associated with negative consequences. Despite some opportunities, the majority of risks have negative results so that individuals only consider negative aspects of risks [3]. Known as complementary part of project management [4], risk management is currently responsible for the most difficult activities of project risk assessment and prioritization [5]. It is also considered a key process so that the majority of project managers acknowledge the necessity of risk management for project management [6]. Risk management is defined as the process of risk identification and assessment and the application of some methods to reduce it to an acceptable level [7]. Therefore, the primary objective of project risk management is risk identification, evaluation and control for the success of projects [8].

Project risk management provides some opportunities such as the emergence of experienced, skilled and classic managers, and gets things organized. The risk management standard published by the Project Management Institute (PMI), entitled Project Management Body of Knowledge (PMBOK), was used in this study as the basic method for describing risk management. The underlying reasons to this selection were general familiarity with PMBOK, easy access to it, simplicity of understanding and application and available supportive resources.

According to the results of Delaram and Ghasemzadeh [9] and Tavakollan and Sohrabi [10] on risk management in construction projects, the factors with the highest impact on the prolongation of the civil projects include the lack of timely supply of sufficient budget, lack of timely resolution of conflicts (traffic, properties, facilities, etc.), unrealistic bidding to win a tender, unfair support from project authorities for [certain] public or private contractors in a tender and during execution, insufficient financial resources of the contractor, poor performance of the contractor in project execution management, poor contractor performance in execution management, prolonged bureaucratic processes in public sectors in dealing with project-related conflicting players, lack of strict laws and regulation in hiring contractors, the lack of a base price list for intracity works, low accuracy in volume estimation, lack of executive and workshop visions in designers, delay in preparation of execution maps, delay in decision making under critical and emergency conditions and weaknesses in design sectors.

Ghanbari and Safae [11] investigated the concept of ISM, determined its paradigmatic origin and described its technical execution steps, key aspects and application in management problems. According to their results, the ISM offers a purposeful order and framework for complex problems and provides decision-makers with a realistic image of their position and involving variables.

Sokhakian and Moeni [12] assessed and ranked risks in water and sewage network projects using a new FMEA approach. They identified 124 risks using different risk identification methods; however, this number of risks was reduced to 63 after consulting with experts in this area. The statistical population included all qualified managers and specialists in the water and sewage development projects. An FMEA-based questionnaire was designed, risk factors affecting project time and cost were introduced, and the impact severity and detection rate were then determined. The figures allocated range from 0 to 10, and the risk priority number (RPN) was calculated by multiplication of these figures, where a higher RPN value indicated a more effective and riskier factor. The new RPN approach used in this study was more precise than the conventional RPN in the risk assessment.

Mohammadi and Jafari [13] also investigated the risk analysis, assessment and management of civil offshore projects using the FMEA method based on the PMBOK. Bibliographic and online resources, opinions of project experts and managers and documents of relevant companies were used to identify risks and monitor the execution of civil offshore projects. The qualitative and quantitative risk analyses were performed through brainstorming and questionnaire, respectively. Then, the risk failure structure and opinions of experts and project managers were used to prepare a list of risks, which may occur during project execution. Finally, the risk probability, the effect of risk on the project's objectives and detection risk were determined for all risks. Among the five critical risks selected for civil offshore projects, "price fluctuation of basic materials" was regarded as the most important risk and some solutions were proposed to reduce it.

Liu *et al.* [14] conducted a study entitled "application of ISM for identification of critical success factors (CSF) of safety management in subway construction". Their results showed that the higher scores of factors related to engineering survey and design in the questionnaire, and also their significant indirect impact on other factors. They also found the significant effect of developing a sound plan and investment on the safety management of subway projects.

Another study on risk assessment was conducted on an offshore pipeline project by combining the ISM and Bayesian network (Wei-Shing *et al.*) [15]. An integrated ISM and Bayesian network (BN) approach was used in this study for risk management. The ISM was used to determine the relationship of different engineering risk factors, shown through the cause-effect diagram. These factors constitute the BN structure. Li *et al.* [16] analyzed safety risk factors in subway construction. Due to its characteristics, they used the ISM to investigate both direct and indirect effects of risk factors and to evaluate the suitability of this method for projects with complex relationships and uncertain structures.

The general objective of this study is to develop a model for the management of risks in water and sewage projects using the ISM. To the best of our knowledge, this is the first study investigating the results obtained from application of the ISM in water and sewage projects.

2. Materials and Methods

The statistical population included all factors involved in water and sewage projects. The Delphi method was used for identification of risks. The ISM was used to rank the causes of different risks. Figure 1 presents seven steps of the ISM.

Step 1: Preparation of the list of relevant variables

In this study, 20 major causes of temporal risks in the water and sewage projects were used as the ISM variables based on consultation with experts and specialists in this area (Table 1.2). S

Step 2: Extraction of the structural self-interaction matrix

The dimensions of the structural self-interaction matrix equal to its variables. Variables in this matrix are organized in the first row and column. The relationships between every two variables are then determined by some symbols. To this end, four symbols presented in Table 1.2 are used.

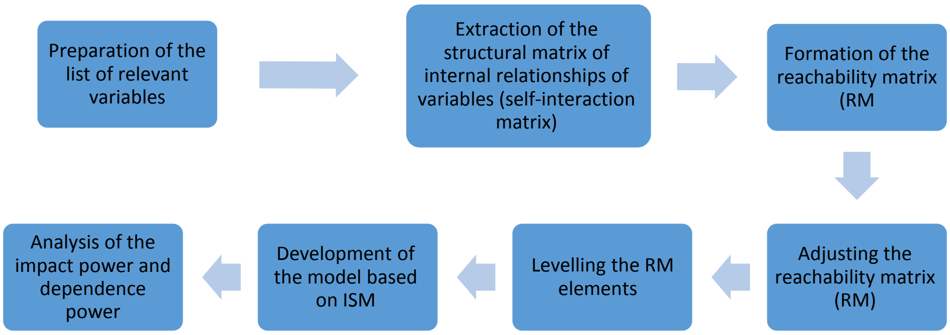

Figure 1: ISM steps

Table 1: (1) Risk factors

Lack of timely notification of adjustment indicators	1
Existence of a tender system and speed in the selection	2
Existence of inexperienced and inefficient chief workshop supervisor	3
Unrealistic contract (selecting the lowest bid)	4
Allocation of Islamic Treasury documents and bills	5
Economic sanction	6
Lack of initial experimental studies	7
Lack of coordination between project designers in construction, electricity, mechanics and architecture contexts	8
Existence of irrelevant maps and details	9
Inaccuracy of initial project estimation	10
Lack of sufficient maps and details	11
Project failure and its conversion into some small projects	12
Selection of indigenous contractors based on the province capacity	13
Delay in granting credits and provision difficulties	14
Natural disasters	15
Workshop accidents	16
Seasonal climatic conditions	17
Inflation and exchange rate fluctuations	18
Lack of or poor counseling	19
Lack of control over detailed scheduling program	20

Table 1: (2) Symbols used in self-interaction matrix

Symbol	Description
V	Variable i affects Variable j
A	Variable j affects Variable i
X	Variables i and j have a mutual relationship
O	Variables i and j are not related

The structural self-interaction matrix in this study was a 19×19 matrix consisted of the most important causes of risk creation in water and sewage projects (Table 1.1).

Step 3: Formation of the initial reachability matrix (RM)

To extract the initial reachability matrix (RM), the symbols in the structural self-interaction matrix (V, A, X, O) are replaced by 0 and 1 based on the following rules:

If the (i, j) entry in the self-interaction matrix is represented by V, the (i, j) entry in the initial RM becomes 1 and the (j, i) entry becomes 0.

If the (i, j) entry in the self-interactoin matrix is represented by A, the (i, j) entry in the initial RM becomes 0 and the (j, i) entry becomes 1.

If the (i, j) entry in the self-interaction matrix is represented by X, both the entries (i, j) and (j, i) in the initial RM become 1.

If the (i, j) entry in the self-interaction matrix shows O, both the entries (i, j) and (j, i) in the initial RM become 0.

Step 4: Adjusting the reachability matrix

After extracting the initial RM, its internal consistency must be established. For example, if the Variable 1 produces Variable 2, and Variable 2 produces Variable 3, Variable 1 should produce Variable 3 in the RM; otherwise, the matrix should be modified and the missed relationships should be substituted. Mathematical rules were used to adjust this matrix. To this end, the K+1th power of the RM should be calculated at $K \geq 1$. However, it is done based on the Laws of Boolean. In this table, numbers marked with * become 1 after the adjustment. Besides, the driving power and dependence power values are obtained by summing all 1 entries in each row and column, respectively.

Step 5: Leveling of risk factors

In this step, the risk factors are categorized into different levels using the reachability matrix. To determine the level of variables in the final model, three sets, namely output, input and hybrid output-input are formed for each variable. The output set includes the variable itself and other variables affected by it. The input set includes the variable itself and other variables affecting that variable. The hybrid output-input set is a combination of these two sets. In the case of similar output and hybrid input-output sets for a variable, that variable is at the highest level of the model. After determining the level of each variable, they are eliminated from the table and a new table is formed with the remaining variables. Similar to the first table, the second table determines the second level variable. This process continues until determining the levels of all variables.

Step 6: Development of ISM

After determining the relationship and levels of the risk causes, they are illustrated in a descending order of priority. The relationships between causes are then determined using directed lines (arrows) based on the final RM.

The resulting model is comprised of multiple levels. The lower-level variables affect higher-level variables. Therefore, the higher-level variables are affected by the lower-level variables. The lowest level has the highest driving power on other causes. The second-level causes have high driving power and dependence power. The first-level causes have the highest dependence as compared to other causes.

Step 7: Analysis of driving power and dependence power (MICMAC diagram)

The MICMAC analysis is used to determine the driving power and dependence power of causes. The causes divided into four groups of variables based on the driving power and dependence power include autonomous, dependent, linking and independent variables. The first group, autonomous variables, have weak driving power and dependence power. These variables are relatively unrelated to the system. The second group, dependent variables, have weak driving power and very strong dependence power. These causes are mainly the results of several involved risks while they, themselves, are less likely to pose other risks. The third group, linking variables, have weak driving power and dependence power. These variables are non-static. In other words, any change in other variables causes a change in these variables and thereby the whole model. The fourth group, independent variables, have strong driving power and weak dependence power. This is the most important group and should be emphasized at the beginning of the system operation. Causes in the independence and linking groups have a stronger driving power for the risk creation. The variables in these two groups are called the key variables.

3. Results

In the present study, expert opinions have been used in water and wastewater projects. After analyzing the data, the final table was completed as as follows. Using the instructions for converting each of the symbols (V, A, X, O), the initial access matrix is obtained in accordance with Table 2. By modifying the initial access matrix with the internal consistency method, the final access matrix is created based on Table 4.

In the next step, to rank the existing risk factors, output set, input set and common set were formed for each variable. The output set contains the variable itself and other variables under its influence and the input set includes the variable itself and other variables affecting it. The common set is also the intersection of the two sets above. The results of this step are shown in Tables 5 to 13.

In MICMAC analysis, the sum of the values of each row is equal to the driving power and the sum of the values of each column is equal to the dependence power of that risk factor. Finally, these values are plotted on the driving power-dependence power diagram.

4. Discussion and Conclusion

As seen in Fig. 2, the causes of the risks in this study were divided autonomous, dependent, linking, and independent variables based on their driving power and dependence power. The first group including the autonomous variables have weak driving power and dependence power. None of the causes were placed in this group. The second group including the dependent variables (1, 4, 13, 16, and 20) have weak driving power and high dependence. These causes are mainly the results of several involved causes resulted from many other causes while they, themselves, are less likely to be the cause of other causes. The third group includes linking variables (5, 7, 8, 9, 10, 11 and 12), which have strong driving power and dependence power. The variables in this group are non-static so that any change in other variables causes a change in these variables and thereby the whole model. The fourth group includes independent variables (2, 3, 6, 14, 15, 17, 18 and 19), which have strong driving power and weak dependence power. According to the results, Variables 5, 7, 8, 9, 10, 11 and 12 with strong driving power and dependence power (probability of occurrence) are among the prioritized

Table 2: Half diagonal matrix containing symbols

	i ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
→ j	V: One-way relation from i to j / A: One-way relation from j to i / X: Bilateral relation from i to j / O: No relation between i and j	No timely notification of adjustment indicators	Tender system and speed in selection	Workshop supervisor with low and inefficient work experience	Weakness in contract type (lowest price choice)	Allocation of Islamic treasury bills and certificates	Economic sanctions	Failure to do initial study tests	Lack of coordination between project designers (buildings, electricity, mechanics and architecture)	Unrelated maps and details	Inaccuracy in initial project estimation	Deficit in maps and details	Failure of a project and its conversion into several small projects	Selection of native contractors according to province capacity	Delay in the notification of credits and difficulty in providing them	Natural disasters	Workshop incidents	Seasonal weather conditions	Inflation and changes in the foreign exchange rate	Not using consultants or using unqualified consultants	No control over the detailed schedule
1	No timely notification of adjustment indicators	-	o	o	o	o	A	o	o	o	o	o	o	o	o	o	o	o	A	o	A
2	Tender system and speed in selection		-	o	v	o	o	o	o	o	o	v	o	v	o	o	o	o	O	o	o
3	Workshop supervisor with low and inefficient work experience			-	o	o	o	o	o	o	o	o	v	A	o	o	v	o	O	A	v
4	Weakness in contract type (lowest price choice)				-	A	A	o	o	A	X	X	X	X	o	o	v	o	A	A	o
5	Allocation of Islamic treasury bills and certificates					-	A	o	o	o	o	o	v	v	X	o	o	o	A	v	A
6	Economic sanctions						-	o	o	o	o	o	v	v	v	o	o	o	v	v	v
7	Failure to do initial study tests							-	v	v	v	v	o	o	A	o	v	o	o	A	X

8	Lack of coordination between project designers (buildings, electricity, mechanics and architecture)								-	v	v	v	o	o	o	o	v	o	o	A	X
9	Unrelated maps and details									-	v	X	o	o	o	o	v	o	o	A	v
10	Inaccuracy in initial project estimation										-	A	v	o	A	o	v	o	A	A	v
11	Deficit in maps and details											-	v	o	o	o	v	o	o	A	V
12	Failure of a project and its conversion into several small projects												-	v	A	A	o	o	A	A	X
13	Selection of native contractors according to province capacity													-	A	A	v	o	A	o	o
14	Delay in the notification of credits and difficulty in providing them														-	A	v	o	A	v	V
15	Natural disasters															-	v	A	v	o	v
16	Workshop incidents																-	A	o	A	v
17	Seasonal weather conditions																	-	o	o	V
18	Inflation and changes in the																		-	v	v

	foreign exchange rate																				
19	Not using consultants or using unqualified consultants																			-	v
20	No control over the detailed schedule																				-

Table 3: Initial access matrix

	I ↙	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
→ J		No timely notification of adjustment indicators	Tender system and speed in selection	Workshop supervisor with low and inefficient work experience	Weakness in contract type (lowest price choice)	Allocation of Islamic treasury bills and certificates	Economic sanctions	Failure to do initial study tests	Lack of coordination between project designers (buildings, electricity, mechanics and architecture)	Unrelated maps and details	Inaccuracy in initial project estimation	Deficit in maps and details	Failure of a project and its conversion into several small projects	Selection of native contractors according to province capacity	Delay in the notification of credits and difficulty in providing them	Natural disasters	Workshop incidents	Seasonal weather conditions	Inflation and changes in the foreign exchange rate	Not using consultants or using unqualified consultants	No control over the detailed schedule
1	No timely notification of adjustment indicators	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Tender system and speed in selection	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
3	Workshop supervisor with low and inefficient work experience	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1
4	Weakness in contract type (lowest price choice)	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0
5	Allocation of Islamic treasury bills and certificates	0	0	0	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0

6	Economic sanctions	1	0	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0	1	1	1
7	Failure to do initial study tests	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	1
8	Lack of coordination between project designers (buildings, electricity, mechanics and architecture)	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	1
9	Unrelated maps and details	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	1
10	Inaccuracy in initial project estimation	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1
11	Deficit in maps and details	0	0	0	1	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	1
12	Failure of a project and its conversion into several small projects	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
13	Selection of native contractors according to province capacity	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
14	Delay in the notification of credits and difficulty in providing them	0	0	0	0	1	0	1	0	0	1	0	1	1	1	0	1	0	0	1	1
15	Natural disasters	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	1
16	Workshop incidents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
17	Seasonal weather conditions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1
18	Inflation and changes in the foreign exchange rate	1	0	0	1	1	0	0	0	0	1	0	1	1	1	0	0	0	1	1	1
19	Not using consultants or using unqualified consultants	0	0	1	1	0	0	1	1	1	1	1	1	0	0	0	1	0	0	1	1
20	No control over the detailed schedule	1	0	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1

Table 4: Final access matrix

j → / i ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Driving power
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	0	1	*1	1	0	0	0	0	*1	*1	1	*1	1	0	0	*1	0	0	0	0	9
3	*1	0	1	*1	0	0	*1	*1	0	0	0	1	*1	0	0	1	0	0	0	1	9
4	0	0	*1	1	0	0	0	0	*1	1	1	1	1	0	0	1	0	0	0	0	8
5	0	0	*1	1	1	0	*1	*1	*1	*1	*1	1	1	1	0	*1	0	0	1	0	13
6	1	0	*1	1	1	1	*1	*1	*1	*1	*1	1	1	1	0	*1	0	1	1	1	17
7	*1	0	0	*1	*1	0	1	1	1	1	1	*1	0	0	0	1	0	0	0	1	11
8	*1	0	0	*1	*1	0	*1	1	1	1	1	*1	0	0	0	1	0	0	0	1	11
9	*1	0	0	1	*1	0	*1	*1	1	1	1	*1	*1	0	0	1	0	0	0	1	12
10	*1	0	0	1	*1	0	*1	*1	0	1	*1	1	*1	0	0	1	0	0	0	1	11
11	*1	0	0	1	*1	0	*1	*1	1	1	1	1	*1	0	0	1	0	0	0	1	12
12	*1	0	*1	1	*1	0	*1	*1	0	*1	*1	1	1	0	0	*1	0	0	0	1	12
13	0	0	1	1	0	0	0	0	0	*1	*1	*1	1	0	0	1	0	0	0	0	7
14	*1	0	0	*1	*1	0	1	*1	*1	1	*1	1	1	1	0	1	0	0	1	1	14
15	*1	0	*1	*1	*1	0	*1	*1	0	*1	0	1	1	1	1	1	0	1	*1	1	15
16	*1	0	0	0	*1	0	*1	*1	0	0	0	*1	0	0	0	1	0	0	0	1	7
17	*1	0	0	0	*1	0	*1	*1	0	0	0	*1	*1	*1	1	1	1	*1	0	1	12
18	1	0	*1	1	1	0	*1	*1	*1	1	*1	1	1	1	0	*1	0	1	1	1	16
19	*1	0	1	1	*1	0	1	1	1	1	1	1	*1	0	0	1	0	0	1	1	14
20	1	0	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	6
Dependence power	16	1	10	17	15	1	16	16	12	16	15	19	16	7	2	19	1	4	7	15	

Table 5: The first iteration in determining the levels of variables

		Output set	Input set	Common set	Level
1	No timely notification of adjustment indicators	1	1, 3, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	1	Level 1
2	Tender system and speed in selection	2, 3, 4, 9, 10, 11, 12, 13, 16	2	2	
3	Workshop supervisor with low and inefficient work experience	1, 3, 4, 7, 8, 12, 13, 16 , 20	2, 3, 4, 5, 6, 12, 13, 15, 18, 19	3, 4, 12, 13	
4	Weakness in contract type (lowest price choice)	3, 4, 9, 10, 11, 12, 13, 16, 19	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20	3, 4, 9, 10, 11, 12, 13, 19	
5	Allocation of Islamic treasury bills and certificates	3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16,19	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 16, 19	
6	Economic sanctions	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20	6	6	
7	Failure to do initial study tests	1, 4, 5, 7, 8, 9, 10, 11, 12, 16, 20	3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	5, 7, 8, 9, 10, 11, 12, 16, 20	
8	Lack of coordination between project designers (buildings, electricity, mechanics and architecture)	1, 4, 5, 7, 8, 9, 10, 11, 12, 16, 20	3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	5, 7, 8, 9, 10, 11, 12, 16, 20	
9	Unrelated maps and details	1, 4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 20	2, 4, 5, 6, 7, 8, 9, 11, 14, 18, 19, 20	4, 5, 7, 8, 9, 11, 20	
10	Inaccuracy in initial project estimation	1, 4, 5, 7, 8, 10, 11, 12, 13, 16, 20	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20	4, 5, 7, 8, 10, 11, 12, 13, 20	

11	Deficit in maps and details	1, 4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 20	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 19, 20	4, 5, 7, 8, 10, 11, 12, 13, 20	
12	Failure of a project and its conversion into several small projects	1, 3, 4, 5, 7, 8, 10, 11, 12, 13, 16, 20	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20	3, 4, 5, 7, 8, 10, 11, 12, 13, 20	
13	Selection of native contractors according to province capacity	3, 4, 10, 11, 12, 13, 16	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20	3, 4, 10, 11, 12, 13	
14	Delay in the notification of credits and difficulty in providing them	1, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 19, 20	5, 6, 14, 15, 17, 18, 20	5, 14, 20	
15	Natural disasters	1, 3, 4, 5, 7, 8, 10, 12, 13, 14, 15, 16, 18, 19, 20	15, 17	15	
16	Workshop incidents	1, 5, 7, 8, 12, 16, 20	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20	5, 7, 8, 12, 16, 20	
17	Seasonal weather conditions	1, 5, 7, 8, 12, 13, 14, 15, 16, 17, 18, 20	17	17	
18	Inflation and changes in the foreign exchange rate	1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20	6, 15, 17, 18	18	
19	Not using consultants or using unqualified consultants	1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 19, 20	5, 6, 14, 15, 18, 19, 20	19	
20	No control over the detailed schedule	1, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 19, 20	3, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	7, 8, 9, 10, 11, 12, 14, 16, 19, 20	

Table 6: The second iteration in determining the levels of variables

		Output set	Input set	Common set	Level
2	Tender system and speed in selection	2, 3, 4, 9, 10, 11, 12, 13, 16	2	2	
3	Workshop supervisor with low and inefficient work experience	3, 4, 7, 8, 12, 13, 16 , 20	2, 3, 4, 5, 6, 12, 13, 15, 18, 19	3, 4, 12, 13	
4	Weakness in contract type (lowest price choice)	3, 4, 9, 10, 11, 12, 13, 16, 19	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20	3, 4, 9, 10, 11, 12, 13, 19	
5	Allocation of Islamic treasury bills and certificates	3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16,19	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 16, 19	
6	Economic sanctions	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20	6	6	
7	Failure to do initial study tests	4, 5, 7, 8, 9, 10, 11, 12, 16, 20	3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	5, 7, 8, 9, 10, 11, 12, 16, 20	
8	Lack of coordination between project designers (buildings, electricity, mechanics and architecture)	4, 5, 7, 8, 9, 10, 11, 12, 16, 20	3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	5, 7, 8, 9, 10, 11, 12, 16, 20	
9	Unrelated maps and details	4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 20	2, 4, 5, 6, 7, 8, 9, 11, 14, 18, 19, 20	4, 5, 7, 8, 9, 11, 20	
10	Inaccuracy in initial project estimation	4, 5, 7, 8, 10, 11, 12, 13, 16, 20	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20	4, 5, 7, 8, 10, 11, 12, 13, 20	
11	Deficit in maps and details	4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 20	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 19, 20	4, 5, 7, 8, 10, 11, 12, 13, 20	
12	Failure of a project and its conversion into several small projects	3, 4, 5, 7, 8, 10, 11, 12, 13, 16, 20	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20	3, 4, 5, 7, 8, 10, 11, 12, 13, 20	

13	Selection of native contractors according to province capacity	3, 4, 10, 11, 12, 13, 16	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20	3, 4, 10, 11, 12, 13	
14	Delay in the notification of credits and difficulty in providing them	4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 19, 20	5, 6, 14, 15, 17, 18, 20	5, 14, 20	
15	Natural disasters	3, 4, 5, 7, 8, 10, 12, 13, 14, 15, 16, 18, 19, 20	15, 17	15	
16	Workshop incidents	5, 7, 8, 12, 16, 20	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20	5, 7, 8, 12, 16, 20	Level 2
17	Seasonal weather conditions	5, 7, 8, 12, 13, 14, 15, 16, 17, 18, 20	17	17	
18	Inflation and changes in the foreign exchange rate	3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20	6, 15, 17, 18	18	
19	Not using consultants or using unqualified consultants	3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 19, 20	5, 6, 14, 15, 18, 19, 20	19	
20	No control over the detailed schedule	4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 19, 20	3, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	7, 8, 9, 10, 11, 12, 14, 16, 19, 20	

Table 7: The third iteration in determining the levels of variables

		Output set	Input set	Common set	Level
2	Tender system and speed in selection	2, 3, 4, 9, 10, 11, 12, 13	2	2	
3	Workshop supervisor with low and inefficient work experience	3, 4, 7, 8, 12, 13, 20	2, 3, 4, 5, 6, 12, 13, 15, 18, 19	3, 4, 12, 13	
4	Weakness in contract type (lowest price choice)	3, 4, 9, 10, 11, 12, 13, 19	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20	3, 4, 9, 10, 11, 12, 13, 19	Level 3
5	Allocation of Islamic treasury bills and certificates	3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 19	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 17, 18, 19, 20	3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 19	
6	Economic sanctions	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 19, 20	6	6	
7	Failure to do initial study tests	4, 5, 7, 8, 9, 10, 11, 12, 20	3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 17, 18, 19, 20	5, 7, 8, 9, 10, 11, 12, 20	
8	Lack of coordination between project designers (buildings, electricity, mechanics and architecture)	4, 5, 7, 8, 9, 10, 11, 12, 20	3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 17, 18, 19, 20	5, 7, 8, 9, 10, 11, 12, 20	
9	Unrelated maps and details	4, 5, 7, 8, 9, 10, 11, 12, 13, 20	2, 4, 5, 6, 7, 8, 9, 11, 14, 18, 19, 20	4, 5, 7, 8, 9, 11, 20	
10	Inaccuracy in initial project estimation	4, 5, 7, 8, 10, 11, 12, 13, 20	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20	4, 5, 7, 8, 10, 11, 12, 13, 20	Level 3
11	Deficit in maps and details	4, 5, 7, 8, 9, 10, 11, 12, 13, 20	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 19, 20	4, 5, 7, 8, 9, 10, 11, 12, 13, 20	Level 3
12	Failure of a project and its conversion into several small projects	3, 4, 5, 7, 8, 10, 11, 12, 13, 20	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20	3, 4, 5, 7, 8, 10, 11, 12, 13, 20	Level 3
13	Selection of native contractors according to province capacity	3, 4, 10, 11, 12, 13	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20	3, 4, 10, 11, 12, 13	Level 3

14	Delay in the notification of credits and difficulty in providing them	4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 19, 20	5, 6, 14, 15, 17, 18, 20	5, 14, 20	
15	Natural disasters	3, 4, 5, 7, 8, 10, 12, 13, 14, 15, 18, 19, 20	15, 17	15	
17	Seasonal weather conditions	5, 7, 8, 12, 13, 14, 15, 17, 18, 20	17	17	
18	Inflation and changes in the foreign exchange rate	3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 18, 19, 20	6, 15, 17, 18	18	
19	Not using consultants or using unqualified consultants	3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 19, 20	5, 6, 14, 15, 18, 19, 20	19	
20	No control over the detailed schedule	4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 19, 20	3, 6, 7, 8, 9, 10, 11, 12, 14, 15, 17, 18, 19, 20	7, 8, 9, 10, 11, 12, 14, 19, 20	

Table 8: The fourth iteration in determining the levels of variables

		Output set	Input set	Common set	Level
2	Tender system and speed in selection	2, 3, 9	2	2	
3	Workshop supervisor with low and inefficient work experience	3, 7, 8, 20	2, 3, 4, 5, 15, 18, 19	3	
5	Allocation of Islamic treasury bills and certificates	3, 5, 7, 8, 9, 14, 19	2, 3, 5, 6, 7, 8, 9, 14, 15, 17, 18, 19, 20	3, 5, 7, 8, 9, 14, 19	Level 4
6	Economic sanctions	3, 5, 6, 7, 8, 9, 14, 18, 19, 20	6	6	
7	Failure to do initial study tests	5, 7, 8, 9, 20	3, 5, 6, 7, 8, 9, 14, 15, 17, 18, 19, 20	5, 7, 8, 9, 20	Level 4
8	Lack of coordination between project designers (buildings, electricity, mechanics and architecture)	5, 7, 8, 9, 20	3, 5, 6, 7, 8, 9, 14, 15, 17, 18, 19, 20	5, 7, 8, 9, 20	Level 4
9	Unrelated maps and details	5, 7, 8, 9, 20	2, 5, 6, 7, 8, 9, 14, 18, 19, 20	5, 7, 8, 9, 20	Level 4

14	Delay in the notification of credits and difficulty in providing them	5, 7, 8, 9, 14, 19, 20	5, 6, 14, 15, 17, 18, 20	5, 14, 20	
15	Natural disasters	3, 5, 7, 8, 14, 15, 18, 19, 20	15, 17	15	
17	Seasonal weather conditions	5, 7, 8, 14, 15, 17, 18, 20	17	17	
18	Inflation and changes in the foreign exchange rate	3, 5, 7, 8, 9, 14, 18, 19, 20	6, 15, 17, 18	18	
19	Not using consultants or using unqualified consultants	3, 5, 7, 8, 9, 19, 20	5, 6, 14, 15, 18, 19, 20	5, 19, 20	
20	No control over the detailed schedule	5, 7, 8, 9, 14, 19, 20	3, 6, 7, 8, 9, 14, 15, 17, 18, 19, 20	7, 8, 9, 14, 19, 20	

Table 9: The fifth iteration in determining the levels of variables

		Output set	Input set	Common set	Level
2	Tender system and speed in selection	2, 3	2	2	
3	Workshop supervisor with low and inefficient work experience	3, 20	2, 3, 6, 15, 18, 19	3	
6	Economic sanctions	3, 6, 14, 18, 19, 20	6	6	
14	Delay in the notification of credits and difficulty in providing them	14, 19, 20	6, 14, 15, 17, 18, 20	14, 20	
15	Natural disasters	3, 14, 15, 18, 19, 20	15, 17	15	
17	Seasonal weather conditions	14, 15, 17, 18, 20	17	17	
18	Inflation and changes in the foreign exchange rate	3, 14, 18, 19, 20	6, 15, 17, 18	18	
19	Not using consultants or using unqualified consultants	3, 19, 20	6, 14, 15, 18, 19, 20	19, 20	Level 5
20	No control over the detailed schedule	14, 19, 20	3, 6, 14, 15, 17, 18, 19, 20	14, 19, 20	Level 5

Table 10: The sixth iteration in determining the levels of variables

		Output set	Input set	Common set	Level
2	Tender system and speed in selection	2, 3	2	2	
3	Workshop supervisor with low and inefficient work experience	3	2, 3, 6, 15, 18	3	Level 6
6	Economic sanctions	3, 6, 14, 18	6	6	
14	Delay in the notification of credits and difficulty in providing them	14	6, 14, 15, 17, 18	14	Level 6
15	Natural disasters	3, 14, 15, 18	15, 17	15	
17	Seasonal weather conditions	14, 15, 17, 18	17	17	
18	Inflation and changes in the foreign exchange rate	3, 14, 18	6, 15, 17, 18	18	

Table 11: The seventh iteration in determining the levels of variables

		Output set	Input set	Common set	Level
2	Tender system and speed in selection	2	2	2	Level 7
6	Economic sanctions	6, 18	6	6	
15	Natural disasters	15, 18	15, 17	15	
17	Seasonal weather conditions	15, 17, 18	17	17	
18	Inflation and changes in the foreign exchange rate	18	6, 15, 17, 18	18	Level 7

Table 12: The eighth iteration in determining the levels of variables

		Output set	Input set	Common set	Level
6	Economic sanctions	6	6	6	Level 8
15	Natural disasters	15	15, 17	15	Level 8
17	Seasonal weather conditions	15, 17	17	17	

Table 13: The ninth iteration in determining the levels of variables

		Output set	Input set	Common set	Level
17	Seasonal weather conditions	17	17	17	Level 9

Table 14: The ninth iteration in determining the levels of variables

Level 1	No timely notification of adjustment indicators (factor 1)
Level 2	Workshop incidents (factor 16)
Level 3	Weakness in contract type (lowest price choice) (factor 4)
	Inaccuracy in initial project estimation (factor 10)
	Deficit in maps and details (factor 11)
	Failure of a project and its conversion into several small projects (factor 12)
	Selection of native contractors according to province capacity (factor 13)
Level 4	Allocation of Islamic treasury bills and certificates (factor 5)
	Lack of detailed preliminary studies (factor 7)
	Lack of coordination between project designers (buildings, electricity, mechanics and architecture) (factor 8)
Level 5	Unrelated maps and details (factor 9)
	Not using consultants or using unqualified consultants
Level 6	No control over the detailed schedule
	Workshop supervisor with low and inefficient work experience
Level 7	Delay in the notification of credits and difficulty in providing them
	Tender system and speed in selection
Level 8	Inflation and changes in the foreign exchange rate
	Economic sanctions
Level 9	Natural disasters
	Seasonal weather conditions

Table 15: Driving power and dependence power

Risk factor number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Driving power	1	9	9	8	13	17	11	11	12	11	12	12	7	14	15	7	12	16	14	6
Dependence power	16	1	10	17	15	1	16	16	12	16	15	19	16	7	2	19	1	4	7	15

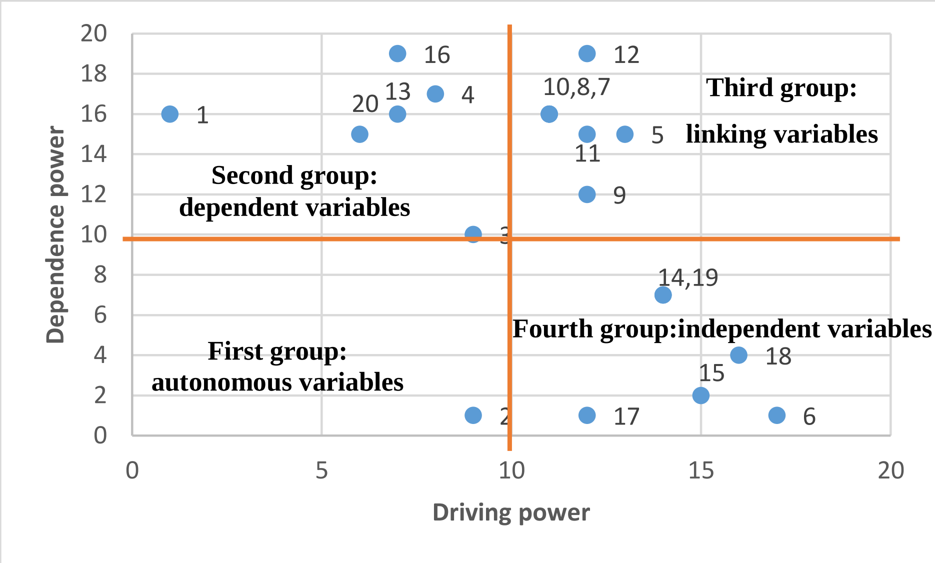

Figure 2: Driving power-dependence power diagram of risk factors

risk factors and should be fully controlled. These factors are allocation of the Islamic Treasury bills and documents, the lack of conduction of preliminary studies, the lack of cooperation among project designers, irrelevant maps and details, inaccurate initial project estimation and failure of the project and its conversion into some smaller projects.

According to the literature on the identification of civil project risks, a broad range of relevant studies addressed only one dimension of the risk, such as economic, social and technical aspects. Among the relevant studies, Mohammadi *et al.* [17], Atashsooz *et al.* [18], and Nikabadi *et al.* [19] did the most comprehensive categorization to identify the supply chain risks of projects. The results reported by Yuan *et al.* [20], Bi *et al.* [21] and Gao *et al.* [22] were used as the main sources to extract the project risk dimensions and indices. An important literature gap on civil project risks is the lack of study proposing a comprehensive model for the water and sewage project risks. Therefore, the results of this study can be used as a risk management model in water and sewage projects. This study aimed at identifying challenges representing a bias element, based on the experts' knowledge. Since this study focused mainly on the water and sewage projects, further research should be conducted to generalize the results to other areas..

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