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An empirical study for ranking risk factors using linear assignment: A case study of road construction

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A R T I C L E I N F O

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A B S T R A C T

Road construction projects are considered as the most important governmental issues since there are normally heavy investments required in such projects. There is also shortage of financial resources in governmental budget, which makes the asset allocation more challenging. One primary step in reducing the cost is to determine different risks associated with execution of such project activities. In this study, we present some important risk factors associated with road construction in two levels for a real-world case study of rail-road industry located between two cities of Esfahan and Deligan. The first group of risk factors includes the probability and the effects for various attributes including cost, time, quality and performance. The second group of risk factors includes socio-economical factors as well as political and managerial aspects. The study finds 21 main risk factors as well as 193 sub risk factors. The factors are ranked using groups decision-making method called linear assignment. The preliminary results indicate that the road construction projects could finish faster with better outcome should we carefully consider risk factors and attempt to reduce their impacts.

1. Introduction

Project risk management (PRM) plays an important competitive advantage for building sponsors, especially for those sponsors who take risks carefully, anticipate significant changes, and protect themselves from many events. Nevertheless, the realization of this advantage on design-intensive multi-disciplinary capital projects relies on the approach to the initial identification of risk. Chapman studied the necessary steps involved for assessment process of risk analysis by examining the quality of the identification and assessment process.

Ng and Loosemore (2007) discussed risk allocation in the private provision of public infrastructure and argued that many people benefit most from the private provision of public infrastructure when project risks are allocated properly between private and public sectors. They explained that there are

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many issues influencing this task such as technical, legal, political and economic complexity of infrastructure projects, etc. There are many cases where the risks are not predicted properly and we face with increase in costs, project delays and services. Ng and Loosemore (2007) investigated a case study of the controversial $920 million New Southern Railway project in Sydney, Australia by analyzing the logic behind decisions on risk distributions between public and private sectors and their outcomes. They suggested a series of guidelines to better manage risks in such projects.

Thevendran and Mawdesley (2004) presented a comprehensive human risk factors in construction projects. They explained how construction practitioners played risk management and in particular human risks factors. They used a questionnaire and personal interviews with construction practitioners. They discovered that human risk factors are, according to the respondents, the most important construction risk, and emphasis the need to incorporate human risk factors into project risk management.

Baccarini and Archer (2001) explained the use of a methodology for the risk ranking of projects undertaken by the Department of Contract and Management Services (CAMS). Klein and Cork (1998) presented a method for assessment of the risk that a particular system such as an aircraft or computer, will not perform to its required performance characteristics when it is developed. The technique is based on decomposition of the system under assessment into a hierarchy of functionally specified assessment areas and in each area; the technique identifies technical risks, and techniques of assessing these risks. The framework presents a systematic structure for selecting assessment methods and integrating results of the use of selected methods into a coherent overall assessment of the system.

Ghosh and Jintanapakanont (2004) proposed a method for identifying and assessing the critical risk factors in an underground rail project in Thailand using a factor analysis approach. They identified nine critical factors with 35 items and the factors obtained through the factor analysis were assessed to gain better insight of their importance and impact on project management. Jannadi (2008) presented a comprehensive study for assessing risks associated with trenching works in Saudi Arabia. Isaksson and Stille (2005) presented a model for estimation of time and cost for tunnel projects based on risk evaluation using FMEA method (McDermott et al., 1996; PMI, 2004; Haimes, 2008).

Xu and Liu (2009) presented an information diffusion technique based on a grid system to assess regional environmental risk. The risk information on a single environmental risk source was diffused effectively using fuzzy set theory. Regional environmental risk values achieved from information diffusion clustered on classification criteria and different environmental risk levels and they were depicted in a spatial partition map. They explained that the results derived from this information diffusion method could help the local government of China optimize the distribution of industrial areas and build risk prevention measurements and emergency management procedures.

The reminder of this paper first identifies the risk factors in section 2 and details of the implementation of our proposed study are given in section 3. Finally, concluding remarks are given in the last to summarize the contribution of the paper.

2. Road construction risk factors

The proposed study of this paper considers the following four stages for assessing risk factors and they are explained in details in the following subsections.

2.1. Questionnaire and feedback collection

The first step is to gather all important factors, influencing the failure of a road construction through designing an appropriate questionnaire, distributing among experts and collecting their feedbacks.

2.2. Preliminary risk assessment

In this step, we calculate the risk involved with each group. Let PIR be the overall risk in each group, P_i be the probability of an unwanted incident, W_i be the performance of each project with $\sum_{i=1}^{4} w_i = 1$ and I_i be the impact of the incident. Therefore, we have,

$$PIR = \sum_{i=1}^{4} W_i \times P_i \times I_i. \tag{1}$$

In our survey, there are four groups of decision makers and they separately send their feedbacks and we calculate six PIRs, leading us to use the following to calculate the overall primary index, $APIR$.

$$APIR = \frac{\sum_{J=1}^{4} (n_j \times PIR_j)}{N}, \tag{2}$$

where n_j is the number of people who participate in each group and $N = \sum_{i=1}^{4} n_j$.

2.3. Secondary risk assessment

As discussed earlier, the preliminary risk factors cannot help us find a complete figure on risk assessment and we need to consider some secondary risk factors.

Let SIR be the overall secondary risk in each group, P_i be the probability of an unwanted incident, W_i be the performance of each project with $\sum_{i=1}^{4} w_i = 1$ and I_i be the impact of the incident. Therefore, we have,

$$SIR = \sum_{i=1}^{4} W_i \times P_i \times I_i. \tag{3}$$

In our survey, there are four groups of decision makers and they separately send their feedbacks and we calculate six PIRs, leading us to use the following to calculate the overall secondary index, $ASIR$.

$$ASIR = \frac{\sum_{J=1}^{4} (n_j \times SIR_j)}{N}, \tag{4}$$

where n_j is the number of people who participate in each group and $N = \sum_{i=1}^{4} n_j$.

2.4. Risk assessment using linear assignment

Now we can use the risk factors obtained from the previous steps as input for the following linear assignment problem formulation.

$$\max Z = \sum_{i=1}^{n}\sum_{k=1}^{n}\gamma_{ik}h_{ik} \tag{5}$$

subject to

$$\sum_{k=1}^{n}h_{ik} = 1, \quad i = 1,\cdots,n \tag{6}$$

$$\sum_{i=1}^{n}h_{ik} = 1, k = 1,\cdots,n \tag{7}$$

$$h_{ij} = 0,1, \quad i, j = 1,\cdots,n \tag{8}$$

where h_{ik} is a binary variable and when it receives a value one, it means that risk factor i maintains k^{th} ranking.

3. Case study

In this section, we present the implementation of the proposed model for a real-world case study of rail-road construction between the cities of Esfahan and Deligan.

3.1 Deligan

Deligan is a city in the capital of Delijan County, Markazi Province, Iran with the population of approximately 32,000 people and it is located 80 km (50 Mi) from Qom and 160 km (100 Mi) from Isfahan. The city is 300 kilometer away from the capital city of Iran and it is in the center of highways connecting various cities. Therefore, the city connects different cities and it plays an important role for domestic transportation.

3.2 External and internal risk factors

We have divided the risk factors into two groups of internal and external ones and they are given in Table 1.

Table 1
Internal (Primary) and external (Secondary) risk factors

Internal	1.Political	2.Social	3.Economical	4.Cultural	5.Natural	6.Domestic
	7.Laws	8.Regulation	9.Planning	10.Commitement	11.development	
External	12.Human Resource	13.Supply chain	14.Project Management	15.contractors	16.Investment	17.Contract
	18.Operations	19. Timing	20.Marketing	21. Industry		

Our group decision-making method consists of four groups of 8, 5, 4 and 7 people and the feedbacks are gathered using Likert five point scale from very low to very high and the points for very low, low, average, high and very high are 0.1, 0.3, 0.5, 0.7 and 0.9, respectively.

The feedbacks are collected based on PMBOK standard in terms of cost, time, quality and the likelihood of the occurrences. Table 2 shows details of the points for different items.

Table 2
PMBOK standard in Likert Scale along with weight factors

Probability	Less than 5%	Very low	0.1
	Between 6% to 25%	Low	0.3
	Between 26% to 50%	Average	0.5
	Between 51% to 70%	High	0.7
	More than 71%	Very high	0.9
Time ($W_1 = 0.3$)	Negligible	Very low	0.1
	Less than 5%	Low	0.3
	Between 6% to 10%	Average	0.5
	Between 10% to 20%	High	0.7
	More than 20%	Very high	0.9
Cost ($W_2 = 0.42$)	Negligible	Very low	0.1
	Less than 5%	Low	0.3
	Between 6% to 10%	Average	0.5
	Between 10% to 20%	High	0.7
	More than 20%	Very high	0.9
Quality ($W_3 = 0.1$)	Negligible	Very low	0.1
	Low	Low	0.3
	Needs approval	Average	0.5
	unacceptable	High	0.7
	Impossible to use	Very high	0.9
Performance ($W_4 = 0.18$)	Negligible	Very low	0.1
	Low	Low	0.3
	Needs approval	Average	0.5
	unacceptable	High	0.7
	Impossible to use	Very high	0.9

3.3 Internal risk assessment

Using the proposed method earlier, we have calculated the internal risk and the results are given in Table 3.

Table 3
Internal risk assessment

Risk	APIR1	APIR2	APIR3	APIR4	APIR	Rank
1	0.0348	0.1032	0.1674	0.336	0.159	19
2	0.5544	0.077	0.5652	0.1698	0.344567	2
3	0.14	0.369	0.0362	0.394	0.244492	12
4	0.2136	0.2982	0.399	0.2484	0.272275	8
5	0.0408	0.1434	0.1914	0.4018	0.192567	15
6	0.316	0.0178	0.284	0.3618	0.2619	10
7	0.0576	0.3276	0.315	0.1374	0.180025	17
8	0.4572	0.4536	0.0942	0.0432	0.2752	9
9	0.07	0.2016	0.081	0.3546	0.182258	16
10	0.276	0.594	0.0876	0.3696	0.33815	3
11	0.1704	0.0478	0.195	0.179	0.151467	20
12	0.194	0.0642	0.1914	0.398	0.226025	13
13	0.1764	0.4878	0.1776	0.2304	0.257225	11
14	0.0248	0.6966	0.0492	0.0386	0.17285	18
15	0.5292	0.1686	0.3626	0.1944	0.328658	4
16	0.1344	0.198	0.4806	0.4312	0.291917	6
17	0.0208	0.0288	0.4998	0.1638	0.144008	21
18	0.306	0.4374	0.1662	0.185	0.274783	7
19	0.6804	0.4592	0.0616	0.0608	0.350467	1
20	0.6084	0.0524	0.322	0.1416	0.308683	5
21	0.3696	0.3402	0.1224	0.022	0.220892	14

3.4 External risk assessment

Using the proposed method earlier, we have calculated the internal risk and the results are summarized in Table 4.

Table 4
External risk assessment

Risk	ASIR1	ASIR2	APIR3	APIR4	APIR
1	R18	R1	R13	R18	R15
2	R20	R3	R9	R10	R14
3	R2	R9	R1	R11	R1
4	R8	R12	R6	R1	R2
5	R4	R21	R7	R2	R3
6	R9	R7	R2	R15	R6
7	R7	R19	R11	R7	R12
8	R17	R10	R16	R14	R17
9	R3	R16	R18	R13	R8
10	R9	R15	R19	R8	R5
11	R13	R4	R20	R3	R10
12	R12	R6	R14	R9	R18
13	R6	R13	R10	R16	R11
14	R21	R20	R3	R19	R20
15	R10	R5	R4	R6	R4
16	R11	R18	R12	R12	R16
17	R15	R8	R5	R5	R7
18	R19	R2	R17	R4	R9
19	R5	R14	R15	R17	R13
20	R14	R17	R21	R21	R21
21	R16	R11	R28	R20	R19

3.5 Input information of the assignment model

Based on the results obtained from the previous part we calculate γ_{ij} as follows,

Table 5
The values of γ_{ij}

R	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	.14	.00	.57	.18	.00	.00	.00	.00	.00	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
2	.00	.00	.11	.36	.18	.21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14	.00	.00	.00
3	.00	.14	.00	.00	.56	.00	.00	.00	.11	.00	.18	.00	.00	.21	.00	.00	.00	.00	.00	.00	.00
4	.00	.00	.00	.00	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.57	.00	.00	.18	.00	.00	.00
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.36	.00	.00	.00	.00	.14	.00	.37	.00	.11	.00	.00
6	.00	.00	.00	.21	.00	.36	.00	.00	.00	.00	.00	.11	.11	.00	.18	.00	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.21	.14	.27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.36	.00	.00	.00	.00
8	.00	.00	.00	.11	.00	.00	.00	.00	.36	.18	.00	.00	.00	.00	.00	.00	.14	.36	.00	.00	.21
9	.00	.21	.14	.00	.00	.11	.00	.00	.00	.00	.00	.18	.00	.00	.00	.00	.00	.00	.00	.00	.00
10	.00	.18	.00	.00	.00	.00	.00	.14	.00	.00	.36	.00	.21	.00	.11	.00	.00	.00	.00	.00	.00
11	.00	.00	.18	.00	.00	.00	.21	.00	.00	.00	.00	.00	.36	.00	.00	.11	.00	.00	.00	.00	.14
12	.00	.00	.00	.00	.00	.00	.36	.00	.00	.00	.00	.11	.00	.00	.00	.39	.00	.00	.00	.00	.00
13	.21	.00	.00	.00	.00	.00	.00	.00	.18	.00	.00	.00	.14	.00	.00	.00	.00	.00	.36	.00	.00
14	.00	.36	.00	.00	.00	.00	.00	.18	.00	.00	.11	.21	.00	.00	.00	.00	.00	.00	.14	.11	.00
15	.36	.00	.00	.00	.00	.18	.00	.00	.00	.14	.00	.00	.00	.00	.00	.00	.11	.00	.21	.00	.00
16	.00	.00	.00	.00	.00	.00	.00	.21	.14	.00	.00	.00	.18	.00	.00	.36	.00	.00	.00	.00	.11
17	.00	.00	.00	.00	.00	.00	.00	.57	.00	.00	.00	.00	.00	.00	.00	.00	.21	.00	.18	.14	.00
18	.29	.00	.00	.00	.00	.00	.00	.00	.21	.00	.00	.36	.00	.00	.00	.14	.00	.00	.00	.00	.00
19	.00	.00	.00	.00	.00	.00	.14	.00	.00	.21	.00	.00	.00	.18	.00	.00	.11	.00	.00	.00	.36
20	.00	.11	.00	.00	.00	.00	.00	.00	.00	.00	.21	.00	.00	.50	.00	.00	.00	.00	.00	.00	.18
21	.00	.00	.00	.00	.14	.00	.00	.00	.00	.00	.00	.00	.00	.11	.00	.00	.00	.00	.00	.75	.00

3.6 Linear assignment model

The proposed assignment problem given in Eq. (5) to Eq. (8) is solved using the input information of Table 5 and the optimal results are calculated. We have also used the data for ranking in terms of traditional method, which is a simple multiplication of risk ratio by its impacts and both results are summarized in Table 6

Table 6
The results of ranking in two methods of Linear assignment (LA) and Traditional method (Tr)

Risk	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
LA	16	2	10	7	15	9	19	13	18	3	17	11	14	21	6	4	20	5	1	8	12
Tr	19	2	12	8	15	10	17	9	16	3	20	13	11	18	4	6	21	7	1	5	14

The proposed model of this paper has different advantages against traditional model. First, it considers different factors, which helps remove systematic risk. The proposed model considers more than two factors and it would consider more realistic items, which makes the results more realistic.

4. Conclusion

We have presented a new risk assessment model based on the implementation of traditional linear assignment. The proposed model of this paper considered two groups of risk factors in terms of internal and external items. A group decision-making technique has been used to rank different risk factors and the results were used for a real-world case study of rail-road construction project located in a city of Deligan. The results of our study seem to perform better than traditional model, which uses only two single factors. In fact, the proposed model uses important factors such as cost, time, quality and other important items, which create a better image on different risks associated with the project.

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References

Baccarini, D., & Archer, R. (2001).The risk ranking of projects: a methodology. *International Journal of Project Management*, 19(3), 139-145.

Chapman, R. J. (2001). The controlling influences on effective risk identification and assessment for construction design management. *International Journal of Project Management*, 19(3), 147-160.

Ghosh, S. & Jintanapakanont, J. (2004). Identifying and assessing the critical risk factors in an underground rail project in Thailand: a factor analysis approach. *International Journal of Project Management*, 22(8), 633-643.

Haimes, Y. (2008). Risk modeling, Assessment, and management. 3rd ed., New York: John Wiley and Sons.

Klein, J.H., & Cork, R. B. (1998). An approach to technical risk assessment. *International Journal of Project Management*, 16(6), 345-351.

Isaksson, T., & Stille, H. (2005). Model for estimation of time and cost for tunnel projects based on risk evaluation. *Rock Mechanic Rock Engineering*, 38 (5), 373–398.

Jannadi, O.A. (2008). Risks associated with trenching works in Saudi Arabia. *Journal of Building and Environment*, 43(5), 776-781.

McDermott, R. E., Mikulak, R. J., & Beauregard, M. R. (1996). *The Basics of FMEA,* New York: Quality resources.

Ng, A., & Loosemore, M. (2007). Risk allocation in the private provision of public infrastructure. *International Journal of Project Management*, 25(1), 66-76.

PMI (Project Management Institute) (2004). *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*, Pennsylvania, USA: Newtown Square.

Thevendran, V., & Mawdesley, M.J. (2004). Perception of human risk factors in construction projects: an exploratory study. *International Journal of Project Management*, 22(2), 131-137.

Xu, L., & Liu, G. (2009). The study of a method of regional environmental risk assessment. *Journal of Environmental Management*, 90(11), 3290-3296.