Analysis of Risk Factors for Highway Construction Projects in Egypt

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Abstract: Egypt construction projects are associated with different levels of risks. The lack of familiarity of project management standards is one of the common risks in the construction industry in Egypt. The main aim of this paper is to identify the most significant risk factors affecting highway construction project in Egypt to decrease the likelihood and impact of those risks. The research method starts with extensive literature review to provide a prime risk factors list which was also augmented to expertise to reach final risk factor list which contains all risks that may be faced during highway construction. Subsequently, a set of 12 risk groups consisting of 73 risks was selected and a questionnaire survey was conducted to determine the likelihood and consequences of the identified risks. Later, a software application was developed using MATLAB to facilitate risk evaluation of highways projects. Results indicated that the risk factors arise from owner side is one of the most common risk factors in the construction industry in Egypt as the owner in the majority of construction project in Egypt is the governmental sector, however, the overall project risk of highway construction projects in Egypt is considered as at a medium level.

Key words: Risk management, highway projects, artificial intelligence, construction in Egypt.

1. Introduction

A risk is defined as the combination of probability of an event and its impacts on project objectives [1, 2]. A positive consequence presents an opportunity whereas a negative consequence poses a threat. The PMBOK (project management body of knowledge) [3] defines a standard process to identify risks, which is based on an iterative process because new risks may evolve or become known as the project progresses through its life cycle.

The Project Management Guideline [4] mentioned that risk identification determines what might happen could affect the objectives of the project, and how those things might happen. It is important to ensure that the widest range of risks is identified as risks omitted at this step may not be analyzed and treated in subsequent steps.

International risk management studies [5-8] were

conducted and reviewed to identify the recent risk factors rise in the construction projects and affect their accomplishment through this. Also, a prime risk factor list was initiated.

Local project risk studies in Egypt [8-10] were focused on pipelines and recently on airport construction. Therefore, the objective of this research is to identify the significant risks that affect the highway construction projects in Egypt.

The developed software can be used to support project managers and construction companies in decision making [11, 12].

In order to facilitate the risk management process for the decision makers in Egypt who are involved in roads construction industry and might did not have the risk management knowledge, a software application is developed to help them in project risk degree assessment.

The research aims to apply complete risk management process on highway construction project in Egypt. Through this process, there will be a list of

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risks in highway construction (risk identification) and definition of the most significant risks through applying evaluation process (applying risk analysis and assessment).

The research based on three main phases is as follows:

- Phase I: risk identification (initiating risk factors list);
- Phase II: risk evaluation (asses risk factors and define the most significant risk factors in highway construction projects);
- Phase III: development of MATLAB application to help decision makers.

In Phase I, extensive literature review on risk management related to highways was conducted to provide a prime questionnaire. In addition, this list was augmented to expertise to reach risk factors list that contains all risk factors that may be faced by highway construction project.

Phase II defines the risks through a questionnaire survey that was conducted on a group of expertise from different sectors (contractor, consultant and owner) and also from different environment (local and international). The objective of this phase is to reach the most significant risks that highway construction projects faced in Egypt.

Phase III deals with developing a software application using MATLAB fuzzy logic. The developed software can be used to support project managers and construction companies in decision making.

2. Research Methodology

The research methodology included two phases: namely risk identification and risk analysis.

2.1 Phase I—Risk Identification

The research work started with an extensive reviewing for past researches concerning risk management containing pervious master thesis, engineering journals and academic published papers.

The literature review was considered to develop the initial risk factors list, parallel with this step, a pilot survey was conducted to reach the second risk factors list. The pilot surveys consider the most important four projects at the moment in Egypt which were:

- (1) the design and supervision upgrading Cairo-Alexandria-Matrouh Desert Road to Freeway Standards;
- (2) upgrading of Greater Cairo Regional Ring Road to an integrated transport corridor;
- (3) the design of Shoubra-Banha Highway project;
- (4) infrastructure construction for Cairo festival city.

During Phase I, it is considered to cover engineering from different fields as civil (road and bridges) and electromechanics which are working for different organizations as clients (The Egyptian Transportation Ministry and The General Authority for Roads, Bridges and Land Transport), consultants (local and international) and contractors.

Combining both risk factors lists after consulting expertise to develop our final risk factors list, identified risks were categorized into 12 groups as follows:

- (1) force majeure risks—it includes risks that are beyond the control of the project sponsors. Such risks include flood and earthquake;
- (2) economical risks—risks that arise due to market downturn and affect the investment negatively or the risks that occur due to economic instability;
- (3) project finance risks—all risks that relate to project cash flow and balance sheets of the project participants;
- (4) standards and regulation risks—this category is concerned with application of standards and regulation throughout the project life cycle;
- (5) sponsor risks—this group includes risks associated to the sponsor;
- (6) design risks—this risk group covers risks that arise during the design stage;
- (7) subcontractor risks—this group is focused on

subcontractors;

(8) equipment risks—this group includes risks attributed to equipment;

(9) site location risks—risks are attributed to location of the construction site;

(10) project staff risks—this group includes risks related to the project resources;

(11) environmental and geotechnical risks—this group gives attention towards risks arise during project construction because of deficiency in geotechnical studies during the design stage of the project;

(12) construction risks—this group contains possible risks during the project execution.

2.2 Phase II—Risk Analysis

Phase II includes a questionnaire survey with a group of experts in order to evaluate risks identified in Phase I. A questionnaire survey was conducted from November 2011 to April 2012. The survey was distributed to 50 experts (40 responses were received out of the 50 distributed questionnaire). The survey covers experts from different backgrounds (civil or electrical surveyors) and interviews were conducted with projects managers, consultant engineers and project engineers, especially those who execute for roads projects. Also, foreign experts who work on some highways infrastructure projects in Egypt were involved.

The survey tried to cover all types of role involved in highway construction. The consultant role was the most frequent type as this depends on two things: first, the consultant involved in the project for longest time period (design and construction) and assigned to solve

construction problem; second, consultant is committed to help the owner in identifying project risks in the beginning of design and the same for contractor in the beginning of construction. The ownership type of participating contractors companies was one of two types mainly in private sector or a public sector, and the most frequent type was the public sector. The respondents were classified according to companies' role as following (consultant, contractor and owner). Consultant was the most frequent type. Expert experience was divided into four categories: juniors (0-5 years) experience, seniors (5-10 years), managers (10-15) and expertise (over 15 years). The survey tried to cover most of the experience range starting from juniors till expert, however, normal distribution had been applied regarding the selection of expert experience. Result of this was the most frequent range of experience of seniors and manger as shown in Fig. 1.

For each risk, experts were asked to assign an impact based on scales presented in Table 1 and the probability for a risk to occur. Then each risk is rated on its probability of occurring and impact on an objective if it does occur. Table 2 shows thresholds for low, moderate or high risks.

3. Analysis and Results

Tables 3 and 4 summarize the questionnaire results for the considered 12 risk categories and individual risk, respectively. Results indicated that risks attributed to the sponsor category have high risk rating. The average risk score of the sponsor risk group is 0.49. The top ranked risk factors (risk score > 0.5) affecting highway

Fig. 1 Questionnaire respondent profile: (a) ownership types; (b) organization role; (c) experience.

Table 1 Sample from risk factors impact on the projects (Group 2).

Risk group	Risk factors	Risk factors definitions
Group 2: financial /economical risks	Corruption	Payment for services or material which the recipient is not due
	Owner bankrupt	A legal status of a person or an organization that cannot repay its duties
	Political changes	Frequent changes in government , protest for change of government or disputes between political parties
	Economical crisis	Applied broadly to a variety of situations in which some financial institutions suddenly lose a large part of their value
	Market inflation	A rise in the general level of prices of goods and services in an economy over a period of time. When the general price level rises, currency buys fewer goods and services
	Variation rate of exchange	An exchange rate between two currencies is the rate at which one currency will be exchanged for another. It is also regarded as the value of one country's currency in terms of another currency
	Taxation risk	The increase in the financial charge or other levy upon a taxpayer or the functional equivalent of a state such that failure to pay is punishable by law
	Variation in raw material prices	Increase the prices of basic material from which a product is manufactured or made, frequently used with an extended meaning

Table 2 Defined conditions for impact scales of a risk on major project objectives.

Project objective	Very low (0.1)	Low (0.3)	Moderate (0.5)	High (0.7)	Very high (0.9)
Cost	Insignificant cost increase	< 5% cost increase	5%~10% cost increase	10%~20% cost increase	> 20% cost increase
Time	Insignificant time increase	< 1 month time increase	1 to 3 months time increase	3 to 6 months time increase	> 6 months time increase
Quality	Minimal impacts	Small reduction	Some reduction	Significant reduction	Key criteria cannot be achieved

Table 3 Probabilities and impact matrix.

Impact probability	Very low (0.1)	Low (0.3)	Moderate (0.5)	High (0.7)	Very high (0.9)
0.90	0.09	0.27	0.45	0.63	0.81
0.70	0.07	0.21	0.35	0.49	0.63
0.50	0.05	0.15	0.25	0.35	0.45
0.30	0.03	0.09	0.15	0.21	0.27
0.10	0.01	0.03	0.05	0.07	0.09

Table 4 Summary results of the questionnaire by risk category.

Risk category	Number of risk per rating class			
	Total	Low	Medium	High
Force majeure	6	5	1	0
Economical	7	1	6	0
Project finance	5	2	1	2
Standards and regulation	4	0	2	2
Sponsor	4	0	0	4
Design	8	0	3	5
Subcontractor	4	1	3	0
Equipment	5	2	0	3
Site location	4	1	2	1
Project staff	11	0	5	6
Environmental and geotechnical	5	1	3	1
Construction	10	1	7	2
Total	73	14	33	26

construction projects in Egypt are delay in making decision, land acquisition and interference from the project owner.

4. Project Risk Assessment Model

A model for project risk assessment was built using the MATLAB fuzzy logic toolbox [7]. The proposed model calculates the average risk for highway construction projects. The model consists of 12 FIS (fuzzy interface system) representing the 12 risk

categories. Every FIS consists of three inputs representing the risk factors with high scores within the risk category. The proposed model includes four stages in order to calculate the project average risk as shown in Fig. 1. The model output is a value between 0 and 10 in which 0 indicates “no risk” whereas a value of 10 represents a high-risk project. In addition, the model output includes three-dimensional surfaces for risk trends as shown in Fig. 2.

A simulation run was conducted to determine the

Fig. 2 Half-structure of the proposed fuzzy model (the number is the value of the risk factor from 0–10 and the risk factor value is the result of the research work).

Fig. 3 A sample output of the proposed fuzzy model.

Table 5 Results of the questionnaire.

Category	Risk	Low (%)	Medium (%)	High (%)	Average impact	Average probability	Risk score	Rating
Force majeure	Earthquake	80	20	0	0.31	0.18	0.06	Low
	Flood	20	60	20	0.64	0.50	0.32	Medium
	Fire	70	30	0	0.21	0.20	0.04	Low
	Tornado	70	30	0	0.29	0.24	0.07	Low
	War	10	70	20	0.80	0.05	0.04	Low
	Revolution	70	30	0	0.33	0.21	0.07	Low
Economical	Sponsor bankrupt	20	70	10	0.57	0.47	0.27	Medium
	Political changes	30	40	30	0.59	0.52	0.31	Medium
	Economic crisis	10	60	30	0.63	0.54	0.34	Medium
	Market inflation	40	40	20	0.54	0.47	0.25	Medium
	Variation rate of exchange	20	60	20	0.58	0.52	0.30	Medium
	Taxation risk	80	20	0	0.23	0.32	0.07	Low
	Raw material prices	20	50	30	0.56	0.51	0.29	Medium
Project finance	Time of payments	0	50	50	0.76	0.62	0.47	High
	Advance payment	50	30	20	0.46	0.44	0.20	Medium
	Project time extension	0	60	40	0.70	0.81	0.57	High
	Procurement plan	30	60	10	0.39	0.49	0.19	Low
	Material procurement	100	0	0	0.20	0.17	0.03	Low
Standards and regulation	Safety regulation	0	50	50	0.67	0.72	0.48	High
	Quality assurance	0	90	10	0.59	0.53	0.31	Medium
	Quality control	0	70	30	0.77	0.49	0.38	High
	Not applying cost control	10	60	20	0.72	0.42	0.30	Medium
Sponsor	Delay in making decision	0	10	90	0.82	0.73	0.60	High
	Interference	0	30	70	0.75	0.70	0.53	High
	Work permits	0	40	60	0.66	0.57	0.38	High
	Short contract duration	0	70	30	0.60	0.65	0.39	High
Design	Road alignment	0	60	40	0.74	0.69	0.51	High
	Design error	10	60	30	0.67	0.47	0.31	Medium
	Traffic flow	0	70	30	0.63	0.69	0.43	High
	Alignment availability	10	80	10	0.61	0.54	0.33	Medium
	Change in design	0	50	50	0.69	0.58	0.40	High
	Scope vagueness	20	60	20	0.57	0.45	0.26	Medium
	Shortage of information	20	40	40	0.68	0.54	0.37	High
	Improper feasibility study	20	30	50	0.69	0.60	0.41	High
Subcontractors	Subcontractor bankrupt	50	50	0	0.33	0.47	0.16	Low
	Subcontractor quality	10	80	10	0.50	0.61	0.31	Medium
	Subcontractor delay	10	90	0	0.47	0.65	0.31	Medium
	Subcontractors	20	80	0	0.44	0.58	0.26	Medium
Equipment	Condition	0	60	40	0.83	0.47	0.39	High
	Availability	0	40	60	0.81	0.54	0.44	High
	Storage	70	20	10	0.45	0.39	0.18	Low
	Maintenance	0	50	50	0.74	0.57	0.42	High
	Mobilization	70	20	10	0.40	0.34	0.14	Low
Site location	Site facilities	50	50	0	0.36	0.37	0.13	Low
	Site security	50	20	30	0.55	0.47	0.26	Medium
	Site mobilization	10	90	0	0.54	0.45	0.24	Medium
	Land acquisition	0	30	70	0.81	0.70	0.57	High

(Table 5 continued)

Category	Risk	Low (%)	Medium (%)	High (%)	Average impact	Average probability	Risk score	Rating
Project staff	Staff training	0	80	20	0.61	0.56	0.34	Medium
	Staff availability	10	50	40	0.70	0.55	0.39	High
	Change in organization	0	90	10	0.51	0.58	0.30	Medium
	Staff teamwork	30	70	0	0.51	0.51	0.26	Medium
	Staff experience	0	90	10	0.76	0.46	0.35	Medium
	Manager experience	10	70	20	0.70	0.47	0.33	Medium
	Project management plan	0	60	40	0.69	0.67	0.46	High
	Consultant experience	0	40	60	0.78	0.56	0.44	High
	Contractor experience	0	40	60	0.80	0.61	0.49	High
	Subcontractor experience	30	20	50	0.68	0.54	0.37	High
	Communication plan	10	40	50	0.73	0.64	0.47	High
Environmental and geotechnical	Environmental factors	30	50	20	0.53	0.60	0.32	Medium
	Subsurface conditions	10	50	40	0.70	0.54	0.38	High
	Geotechnical survey	30	60	10	0.45	0.43	0.19	Low
	Dewatering	20	70	10	0.49	0.45	0.22	Medium
	In-accurate survey	20	80	0	0.59	0.43	0.25	Medium
Construction	Contract terms	20	60	20	0.64	0.40	0.26	Medium
	Delay in approvals	10	70	20	0.63	0.53	0.33	Medium
	Conflicts	20	80	0	0.53	0.46	0.24	Medium
	Productivity	0	40	60	0.78	0.57	0.44	High
	Defective work	20	50	30	0.60	0.51	0.31	Medium
	Failure of work	40	60	0	0.52	0.36	0.19	Low
	Changing need	20	80	0	0.53	0.53	0.28	Medium
	Rework	30	70	0	0.51	0.44	0.22	Medium
	Project delay	10	90	50	0.67	0.58	0.39	High
	Claims	10	80	10	0.50	0.63	0.32	Medium

overall average risk factor for highway projects in Egypt using the questionnaire data. Model results indicated that the overall risk value for the highway construction project in Egypt is equal 7 of 10. The result indicates that highway construction projects in Egypt are considered as medium to high risk (Table 5).

5. Conclusions

Results of this research indicate that the most significant risk factors are delay in making decision and land acquisition (Figs. 2 and 3). These factors have risk values more than 50% and likelihood over 70%. The most significant risk factors affecting highway construction in Egypt are risks that frequently occur during project life cycle and have high impact on project accomplishment. A fuzzy logic model was developed in order to evaluate project risk. Based on

the model, the overall risk in the highway construction projects in Egypt is considered at a medium level and hence needs to deploy the use of proper risk management.

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