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Developing an Assessment Model for Factors Affecting the Quality in Egyptian Roads Construction

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Abstract

A new assessment model was developed in this work. The developed model introduced a new approach and reference for assessing the factors affecting the quality in Egyptian roads construction using the fuzzy logic system. Fuzzy logic system was chosen to be used in this research because of its suitability for uncertain or approximate reasoning that involves human intuitive thinking. In addition, it requires a little data to achieve the aim of the proposed model. A field survey was used with construction practitioners in the field of roads projects across Egypt. The proposed model was then evaluated and applied using the data that was collected from the field survey. The results of the study proved that the proposed model can be successfully used in the assessment of factors affecting quality in Egyptian roads construction. The major factors that found to be significantly affecting the quality in construction of these projects were identified according to their importance as; *1) Poor quality of local materials*; *2) Defective workmanship*; *3) Poor quality, performance control, and supervision and 4) Changes in the materials prices.* The proposed model is considered as a general model that can be easily adapted and applied to other types of projects.

Keywords:

Quality, Fuzzy logic, Egyptian roads

1. Introduction

Roads construction is considered one of the most important construction industries allover the world. They are vital arteries for economy and development for any nation/country. Furthermore, road transport is considered one of the most common modes of transport with its role of connecting people, business, services and other activities (Mathew and Rao, 2007). Globally, road construction has many challenges related to environmental factors, social justices, economical state, building materials, method of construction and safety factors requirements (Skinner 2008 and Dornan 2002). Thus roads construction became an important target in modern society or any area subject to a development.

In Egypt, recently, road construction projects is one of the most important infrastructure projects for their role in supporting the new cities, industrial areas and reclamation projects that have been executed to solve the problem of over population growth. Accordingly, Egyptian government has constructed a network of highways covering all different regions across Egypt and extending for around 48,100 Km in 2007 according to the data supplied from Egypt State Information Center (ESIC, 2011). Egyptian government increased the annual budget specified for infrastructure projects, especially roads construction in order to support the proposed improvement in this field. The significant contribution of roads construction projects to the national economy and the large number of jobs they offer are the main reasons of the great attentions that should be given to such projects.

The most important problem, which faces the project managers of the construction projects in developing countries, is the lack of detailed and documented previous data regarding the factors affecting quality in their projects. Accordingly, the technologies and deployment of project management strategies for road construction projects in Egypt are very essential to overcome such challenges and to improve the quality of construction. Fuzzy set theory was chosen in this research because it provides a useful way to deal with ill-defined and complicated problems involved in the vagueness decision-making environment. It can overcome the problem of the shortage in the detailed and documented previous data that concern with the factors affecting quality in construction projects. Fuzzy logic was first introduced in 1965 by Lotfi A. Zadeh with the concept of fuzzy sets as an extension of the classical set theory formed by crisp sets (Zadeh, 1965). Later Zadeh defined the whole algebra of fuzzy logic (Zadeh, 1973), which uses fuzzy sets to compute with words as an extension of the proper operations of the classical logic. In most cases, the fuzzy logic system is a nonlinear mapping of an input data vector into a scalar output, where this relation is defined by linguistic expressions that are obviously computed in numbers. Thus, the fuzzy logic system is considered unique for its ability to handle numerical data and linguistic knowledge.

2. The Research Aim

The overall aim of the research discussed in this paper is to develop and apply a new model that requires little data to assess the factors affecting the quality in Egyptian roads construction.

3. Factors Affecting Quality

The aim of factors identification is to comprehensively identify all significant sources of factors affecting a certain project's objective, as well as the causes of those factors. Chapman (1995) stated that one possible way of understanding and structuring the risks that face any project is to combine the holistic approach of general systems' theory with the discipline of a work breakdown structure as a framework. Tummala and Burchett (1999) mentioned that the Work Breakdown Structure (WBS) assists in the identification of factors by simplifying the project structure into smaller units. This is in order to accurately estimate the project's cost and analyze correlations that may exist between any two cost entries. Issa (2010) introduced sixty five factors that affect the Egyptian infrastructure industry objectives as shown in table (1). These factors were used in this research to be applied on the quality of Egyptian roads construction.

4. Field Survey and Data Collection

Due to the lack of accessible organized information related to the probability of occurrence of the factors affecting the quality of the Egyptian construction industry, a questionnaire was designed using the sixty five factors introduced by Issa (2010) to obtain information on the probability and impacts of the factors on the quality. The approach of the questionnaire is well-recognized and widely used in general management and project management research (ASCE Construction Survey (1979), Bing et al. (1999), Shen et al. (2001), and Thomas et al. (2003)). Direct (face-to-face) delivery was used in most of the questionnaire filling to motivate respondents and to ensure the accuracy of answers and improve response rate as stated by Long et al. (2004). The designed questionnaires were directed towards the three partners in the construction industry groups: owners and their representatives of the roads projects, engineering consultants, and contractors working in roads works.

4.1 Summary of the questionnaire outputs

117 questionnaires were distributed in the period from April 2010 to October 2010. The total number of respondents participating in this survey was 76. As for the total sample, 35 out of 45 questionnaires were received from contractors, 22 out of 32 from consultants and 19 out of 40 copies were received from owners as shown in table (2). The response rates from the different groups were 78%, 69% and 48% from contractors, consultants and owners respectively with average response rate of 65%. The contractors give the highest frequency with 46% and consultants come in the second position with 29%. The lowest frequency was owners' with 25%.

Table 1: Factors affecting quality in the Egyptian construction industry, (Issa 2010)

Political (POL) 1-Loss or delay due to war, revolution, and riot 2-Political risks in countries of suppliers, owners, and contractors **Financial and economical (FIN)** 3-Currency exchange difficulties 4-Increase of inflation rates 5-High taxation and Tax rate changes **Market conditions (MRK)** 6-Fluctuations in market demand for product or service 7-Unfairness in tendering and Method of Contractor choice 8-Market suitability for advanced technology 9-Shortage of transportations and communications 10-Poor quality of local materials **Acts of God (AOG)** 11-Force majeure 12-Severe weather conditions **Design (DES)** 13-Code changes 14-Inadequate specifications and shortage of design data 15-Design errors and omissions 16-Design changes 17-Delay in design and regulatory approval 18-Variations of actual quantities of work compared with quantities in bidding documents **Project financing (PFI)** 19-Lack in project financing 20-Fluctuation of project cash flow 21-Bond policy problems in banks 22-Inadequacy of project insurance (during construction)	**Administrative and Job Site (AJS)** 23-Non confirmation of site boundaries 24-Delay in possession of site 25-Limited working hours and difficulties in access to the site 26-Inadequate of Existing facilities 27-Improper site stores management such as storage and protection of material 28-Poor site safety 29-Unforeseen site conditions such as soil conditions, groundwater and historical finds **Environmental (ENV)** 30-Environmental protection due to project pollutions (noise, smoke, and wastes caused by project) 31-Side effects due to project activities **New technology and constructability (TEC)** 32-Improper design for the usual methods of construction 33-Problems in technology implementation and feasibility of construction methods 34-Defective workmanship 35-Familiarity of the work and Project complexity 36-Poor productivity of manpower or equipments 37-Shortage of required equipment **Procurement (PRC)** 38-Long lead items equipment and bulk material 39-Delay in materials delivering 40-Changes in the materials prices	**Project Contract (CNT)** 41-Contract dispute results from disagreement over some conditions in contracts 42-Breach of contract 43-Contractual failure **Project team (TEM)** 44-Inadequate project organization structure 45-Lacked appropriate skills 46-Poor Communication, coordination and different opinions among team members 47-problems among project team members 48-Changes in core team 49-Inadequate Motivation for workers 50-Improper accommodations for workers **Project stakeholder's (STK)** 51-Lack of Client's experience 52-Client's representative problems 53-Poor communication and coordination among the project team work and other partners (Client, consultant,) 54-Third party delay 55-Delayed dispute resolution **Project management (MNG)** 56-Scheduling errors and underestimation of cost 57-Inadequate project management budget 58-Inadequate site management staffing 59-Inadequate definition of authority and responsibility for any partner 60-Poor quality, performance control, and supervision 61-Inadequate and slow decision-making mechanism 62-Change order control 63-Delay of regulatory reporting 64-Problems resulted in interference among different subcontractors 65-Fluctuation default of Subcontractor

Table 2: Questionnaire Returns Rate and Frequency of Participation

Respondents	Contractor	Consultant	Owner	Total
Questionnaire distributed	45	32	40	117
Responses received	35	22	19	76
Response rate (%)	78%	69%	48%	65%
Frequency of participation	46%	29%	25%	100%

4.2 Respondents' experience

The strength of respondents' experience indicates the degree of reliability of the data provided by them. Fortunately, about 31.6 % of the professionals who participated in this survey have over 20 years of experience, which in turn raises the reliability of the data collected from the shared knowledge of long years of experience in the infrastructure works in Egypt. Also, to ensure that the survey results were credible, any replies from respondents with less than five years of experience were discarded. As shown in table (3), it can be found that a percent of 23.7 % of the participants, have experience of 15-20 years. The frequency of respondents who have experience between 10 to 15 years is 21.1 % of total respondents, whereas, the rest of them (23.7 %) had 5–10 years of relevant experience. The average working experience of all respondents was 15.3 years in the roads construction projects thus the opinions are thought to reflect the real situation in this industry.

Table 3: Years of Experience for the Respondents

Years of experiences	5-10 years	10-15 years	15-20 years	> 20 years	Total
No of respondents	18	16	18	24	76
Percent from sample	23.7%	21.1%	23.7%	31.6%	100.0%

4.3 Agreement analysis

It is not practical to separate the analysis of results for each of the three participants groups (contractors, consultants and owners). To facilitate the presentation of the results, it demonstrated a consensus among the participants through statistical tests. The Ranking agreement factor and percentage agreement test was used to ensure the high agreement between the respondents groups (contractors, consultants, and owners). This had been for ranking the factors before a full analysis for them and their groups could be introduced based on the outcome from all respondents.

The rank agreement factor *RA*, and the percentage of agreement *PA* were calculated for ranking the sixty five factors affecting quality based on their probability of occurrence and the impact on quality for different pairs of groups as introduced by Aniekwu and Okpala (1987, 1988), and Okpala and Aniekwu (1988). The analysis assumed that an absolute difference in rank of two, for example, implies that the groups agreed more than when the absolute difference in rank is three, even though for each case there was no perfect agreement. A lower value for *RA* implies a closer agreement between the two groups, while a factor of zero implies perfect agreement. The value of *PA* should be higher than 50% to represent a good agreement between two groups. Table (4) shows the calculated values of *RA* and *PA*.

Table 4: Rank Agreement Factor *RA* and Percent of Agreement *PA* for the Probability of Occurrence and the Impacts on Quality of Factors for Different Pairs of Groups

Group	Probability		Impact on quality	
	RA	***PA***	***RA***	***PA***
Contractors & Owners	11.66	72.30	11.63	68.15
Contractors & Consultants	12.85	63.18	12.75	53.15
Owners & Consultants	10.55	74.21	11.12	74.16

From Table (4), it can be clearly seen that all of percents of agreements *PA* are higher than 50%, which represent a good agreement among all pairs of groups. The range for the probability percent of agreement was between 74.21% and 63.18 %. For the percent of agreement, there is a close agreement between all groups in their perceptions of the probability of occurrences for the factors probability, and a closer agreement in their perceptions of owners and consultants. For the sixty five factors that contributed to skill importance, the maximum value of *RA* is between contractors and consultants in case of probability of occurrence. The lower values of *RA* are (10.55 and 11.12) for agreement between owners and consultants were found in case of probability of occurrence and impact on quality respectively. It can be concluded that the highest agreement for all groups was found between owners and consultants in all cases due to high values of *PA* and low values of *RA*.

Based on the high degree of agreement between the three groups in ranking, the proposed model used the probability of occurrence and the impact on the quality of the sixty five factors using results of the total number of respondents.

5. Fuzzy Assessment Model for Quality (*FAMQ*)

The aim of the proposed model is to assess the factors affecting quality in the construction industry in an acceptable and easy way. It depends on the relationships between the factor's probability of occurrence and its impact on the quality of the project (if it does occur).

The crisp inputs used in this model are two indices: probability index (*PI*), and impact index for quality (*IIQ*) as introduced by Issa (2010). In order to assess the factors affecting quality, a new quality factor index is represented as the output of this model, namely Fuzzy Index for Quality (*FIQ*). *FIQ* indicates the importance or the magnitude of a certain factor to assess the expected quality. Figure (1) shows the inputs and output for the proposed model.

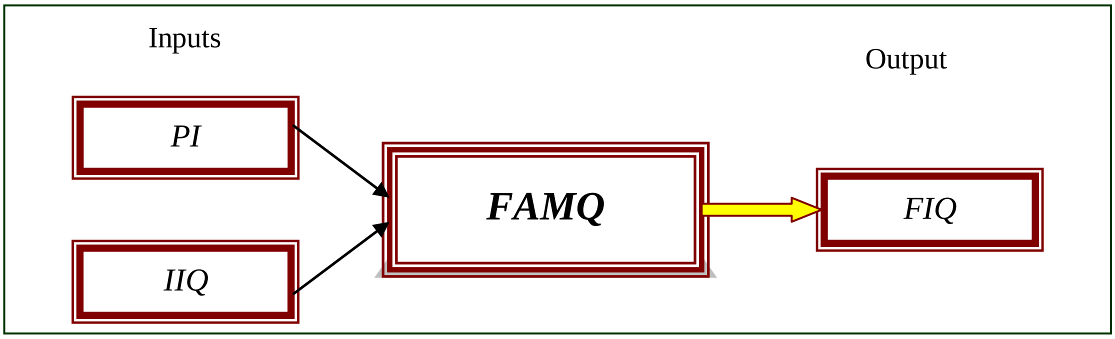

Figure 1: Inputs and Outputs for the Proposed Model

5.1 Membership functions

The membership function represents the fuzziness degree of linguistic variables (Zadeh, 1965). Membership functions were established to give a numerical meaning for each label. Each membership function identifies the range of input values that corresponds to each label. Unlike Boolean logic, the membership function of each label does not define boundaries, where the label is fully applied to one side of a cutoff and not at all to the other side of the cutoff.

The membership function used in the *FAMQ* is the triangle shape for all factors inputs and outputs sources as shown in Figure (2). This membership function was used in many models within the field of construction management and was chosen depending on pervious researches' work. This shape of membership function was used by Tah and Carr (2001) in their factors' assessment model using the cause and effect diagrams. Moreover, it was used by Dikmen, et al. (2007) to rate the cost overrun risk in international construction projects. Hsieh et al, (2004) also used the same shape of the membership function in selecting planning and design alternatives in public office building.

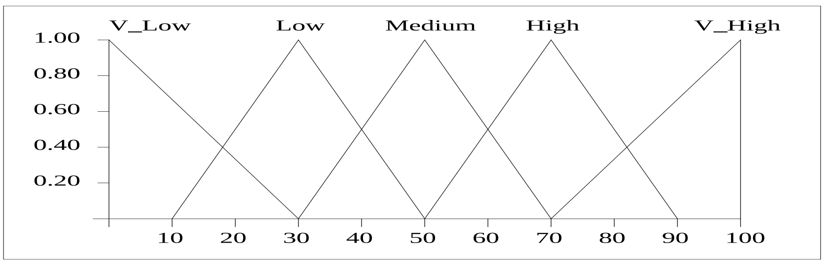

Figure 2: Membership Functions Used in the Proposed Model

The linguistic description assigned to a fuzzy set in this model was taken similar to the labels used in the field survey. For example, the probability of occurrence for a certain factor, the fuzzy label could be: very low, low, medium, high, or very high. Each label was associated with a fuzzy set as shown in

Figure (2). The evaluation of the chosen membership function is checked using the two indices of overlap ratio, and overlap robustness as introduced by Zadeh (1965).

5.2 Aggregation rules

Fuzzy logic is basically logic with multiple values, including several logical rules by explaining how the linguistic labels are related to the means in constructing fuzzy systems. Each fuzzy contains the antecedent and the consequent that includes fuzzy propositions. These propositions in turn are statements that join the linguistic variables with linguistic operators. The fuzzy rule allows values between the conventional evaluations of the precise logic 1 and 0. It also includes operations for 'and', 'or', 'not' and 'if-then'.

In the majority of fuzzy modeling, only the linguistic operator "*AND*" is used to join the linguistic labels of the antecedent, whereas the consequent is formed by only one linguistic label (MISO systems). Aggregation rules in the *FAMQ* follow the common sense behavior of the system and are written in terms of membership function linguistic labels. The factor magnitude can usually be assessed by considering two fundamental factor parameters; likelihood and severity as stated in HSE (2003). Therefore, the relationship in this model (two inputs and one output system) is needed to introduce logical rules for the two inputs (probability of occurrence and impact for each factor), which are considered the only available data.

Assuming there is a relationship between the two inputs probability of occurrence for a certain factor and is represented by its probability index (*PI)* and the impact of the same factor on a project quality is represented by its impact index for quality (*IIQ*). The output of the model (the importance or magnitude of the factor) is represented by fuzzy index for quality (*FIQ*). This relation can be represented by a double premise rule such as:
If the *probability of occurrence* and *Impact on quality* then *factor magnitude*
There are many relationships with varying values of *PI*, *IIQ*, and *FRIQ*. These relationships can be represented using fuzzy associative memories (FAMs), using the method suggested by Kosko (1992) and used by Tah and Carr (2000 and 2001). The interrelationships in the FAMs are taken similar to those introduced by Tah and Carr (2001). The rules can be readily represented by the matrix shown in Table (5).

Table 5: FAMs Rules Used to Calculate the Output of the Proposed Model

Factor Scale		Impact Index for Quality (IIQ)				
		V Low	**Low**	**Medium**	**High**	**V High**
Probability Index (PI)	**V Low**	V Low	V Low	Low	Low	Medium
	Low	V Low	Low	Low	Medium	Medium
	Medium	Low	Low	Medium	Medium	High
	High	Low	Medium	Medium	High	V High
	V High	Medium	Medium	High	V High	V High

In the proposed model, Zadeh Operators are limited to use of (*AND*) only. This is referred to as *minimum* or *min. inferencing*. The process for determining the result or *rule strength* of the rule is done by taking the minimum fuzzy input of (antecedent 1 *AND* antecedent 2, *min. inferencing)*. This minimum result is equal to the consequent rule strength. If there are any consequents that are the same, then the maximum rule strength between similar consequents is taken and is referred to as *maximum* or *max. inferencing*, hence *min./max. inferencing*. This infers that the rule that is most true is taken. These rule strength values are referred to as *fuzzy outputs* $(FIQ = PI \wedge IIQ)$, Where $\wedge$ refers to the intersection between the two inputs. All rules which are used in this model have a weight equal to one.

Once identified, the probability of occurrence, the impact of an individual factor as well as its importance can be assessed using the *FIQ*, which can be computed using the proposed model. According to the FAMs used in this model there are twenty five rules are used.

6. Evaluation and Application of (*FAMQ*)

The *FAMQ* was applied for data acquired from the field survey which concerns the sixty five factor affecting quality to the Egyptian roads construction. Two indices were calculated and used as inputs for this model: The *PI*, and *IIQ*. The model output was the *FIQ* that can be used for assessing the factors affecting quality. In order to evaluate the results of this model, the factors were ranked due to their severity, which can be calculated as the magnitude of the probability of occurrence multiplied by the impact of the factor. The severity index for quality (*SIQ*) was calculated from ($SIQ = PI * IIQ$). The correlation coefficient was calculated using the Spearman's test for ranking the factors due to *FIQ* and *SIQ*. The value of it was 0.944. This high value is very close to +1 which means that the ranks of both coefficients increase together and the relationship between the ranking due to model and due to severity is almost linear.

7. Ranking Factors due to their *FIQ* Values

As stated by Issa (2010), many factors affecting quality have a significant difference in their ranking due to their probability of occurrence and their impact on quality. The proposed model introduced a good insterument to assess the factors based on a combined effect for both the probability and impact.

Table (5) shows the ranking of the top 10 factors due to their *FIQ*. According to ranking due to *FIQ*, the *Poor quality of local materials* factor was the most important factor that affects the quality in Egyptian roads construction. The *Defective workmanship* factor comes in the second place in ranking using *FIQ* while *Poor quality, performance control, and supervision* and *changes in the materials prices* comes in the third and fourth position respectively.

Table 5: Ranking of Top 10 Factors Affecting Quality in Roads Construction Due to Their *FIQ*

Factor No	Factors affecting quality	Rank due to *FIQ*
10	Poor quality of local materials	1
34	Defective workmanship	2
60	Poor quality, performance control, and supervision	3
40	Changes in the materials prices	4
37	Shortage of required equipment	5
65	Fluctuation default of Subcontractor	6
39	Delay in materials delivering	7
27	Improper site stores management such as storage and protection of material	8
19	Lack in project financing	9
12	Severe weather conditions.	10

8. Conclusions

The results of this paper presented a new model (*FAMQ*) which can be used in the assessment of factors affecting quality in the construction projects. With assistance of a designed practical survey, the paper identified and assessed the factors affecting the quality in construction of roads projects in Egypt, as a case study of the construction industry projects. The agreement test was used to test the strength of associations between the rankings of the respondent groups. The results showed that there is high agreement among the contractors, consultants and owners in terms of the probability and the impact on quality of these factors ranking. Therefore, development of the proposed model was based on data of the average of all respondents of the groups.

The developed model introduced a new reference for assessing the factors that could possibly affect the quality in Egyptian roads construction. The model employed the combined effect of both; the factors probability of occurrence and their impacts on the quality of construction using the fuzzy logic system. The new reference represented the magnitude as well as importance of the factors affecting quality. The model was evaluated using the collected data from the field survey of sixty five factor affecting quality of the roads projects in Egypt. The model is flexible and easily updateable to suit any other types of projects or countries. It allows assessing all types of factors that affect construction projects objectives.

The results from applying the model indicated that *Poor quality of local materials; Defective workmanship; Poor quality, performance control, and supervision and Changes in the materials prices* are the top-ranked factors affecting quality of construction in the roads projects in Egypt. The results provided a clear comprehensive image to the Egyptian government and firms planning to establish their businesses in Egypt. The results help them in having in-depth understanding of the factors affecting quality in the Egyptian construction industry. Such understanding is very important for implementing further effective measures to ensure the right direction of future development and create a more attractive market to infrastructure projects professionals.

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