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Assessment of Quality in Saudi Arabian Roadways

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ABSTRACT

Roadways projects in Saudi Arabia are influenced by many factors which have impacts on the quality of these projects. This paper presents the results of an investigation study concerns the assessment of factors affecting the quality of roadways in Saudi Arabia through introducing a proposed technique using the fuzzy logic system. The new technique presented a new method and references for evaluating factors that control the quality of Saudi Arabian roadways. The fuzzy logic has been used due to its ability for combining many effects such as the possibility of occurrence and the influence of factors on the quality of roadways construction. The methodology of this research included designing a questionnaire with experts in the field of roadways execution and design. The new technique was assessed and implemented based on the information that got from the field investigation analysis. The introduced results confirmed that the new assessment technique can be effectively utilized in evaluating the factors controlling quality in roadways. The main factors which are considered with high effects on the quality of roadways projects in Saudi Arabia were identified due to their importance as; 1) Change order due to owner new requirements; 2) Subcontractors Problems and Instability; 3) Delays due to Consultants and Owner representative 4) Contract disputes. The new technique can be classified as a universal method that can be simply improved and implemented to similar categories of projects all over the world.

Keywords: Quality, Fuzzy, roadways, Saudi Arabia

I. INTRODUCTION

Roadways' projects represent the main infrastructure engineering projects all over the world. They are considered dynamic ways for the development for all countries. The roadway works include compound phases and significant activities for any area economic or social growth [1]. Furthermore, roadways projects are rated as one of the most common projects due to their roles in joining persons, facilities and other daily events. Globally, roadways projects face many barriers including environmental, social and economic factors as well as many techniques of construction and safety factors necessities [2]. Thus, roadways projects represent an important goal in recent civilization besides all countries that subjected to high growths.

Roadways projects have great characters in executing modern towns, new industrial regions as well as reclamation areas which can be implemented for participating in extending the new urbans. In Saudi Arabia, roadways projects have become very important due to the great expansion of urbanization. Accordingly, Saudi government has executed an enormous network of roadways extending to all areas in the Kingdom.

Roadways projects, such as all civil and infrastructure projects, face several problems through execution stage. The shortage of completed and predictable earlier information concerning the factors controlling the quality of such projects represent the most important problem. Consequently, the techniques and arrangement of construction plans for roadways projects in Saudi Arabia can be considered very critical for overcoming the expected barriers as well as executing the required specifications in these projects. Fuzzy logic technique was selected in this study since it offers a valuable technique to overcome the problem of imprecise and complex problems in the imprecision decision-making problems. Fuzzy logic can deal with the little, undocumented and undetailed data problem that concern the barriers controlling quality in roadways projects. Fuzzy logic was invented by Zadeh based on the idea of an expansion for the outdated fuzzy theory which utilized the crisp groups [3]. Fuzzy sets were utilized to calculate linguistics as an extension of the correct processes of the traditional theory. In many circumstances, the fuzzy logic technique is represented as nonlinear mapping of the data used for feeding the system or model, wherever this relation can be introduced as linguistic variables that are clearly determined in numbers. Therefore, the fuzzy logic technique can be presented as an exceptional theory due to its capability to determine the mathematical data and linguistic variables.

Many recent researches concern barriers and factors affecting roadways were conducted. For example, researches concern construction roads materials problems were introduced such as the polymer effects on the moisture sensitivity of asphalt mixes [4]. Furthermore, the effect of recycled mill fly ash which is used for improving weak subgrade layers in pavement process by executing a many laboratory experimental tests [5]. The physical and mechanical characteristics of the buildings and destruction wastes were evaluated and introduced for the purpose of roadways construction, especially in sub-base materials [6]. For assessment roadways, a synthesis method was introduced for the purpose of evaluating multi-hazard in roadways infrastructure [7].

Studying the effect of climatic changes was also conducted for reducing the climatic impacts on roadways construction [8] as well as calculating the contents of professional training through executing and operating highways in the special climatic regions [9]. An investigation was introduced for evaluating the environmental effects in the inputs and outputs flows, in addition to the cost increase in the execution of a roadways [1]. Moreover, the factor structure of safety climate inside roadways execution using a safety climate field survey technique was also determined [10]. Another study concluded that road crash severities can be minimized by introducing road lighting and improving road surfaces [11].

Other researches concerned problems due to traffic were also introduced such as evaluation for safety in the traffic flow that comprises construction dump trucks [12]. In Saudi Arabia, limited studies concern roads and traffic were introduced. A study for evaluation the most public traffic signs that utilized in Saudi Arabia was presented [13]. These signs are typically approved from the North American standards and may or may not be suitable for Saudi Arabia due to population effects. Additional study in Saudi Arabia explored the influence of “Saudi Vision 2030” on road traffic safety [14]. A study recommended necessary usage of safety seat belts in cars and using a new records for the purpose of gathering and analyzing data concerning road traffic accidents in Saudi Arabia [15]. The shape of injuries due to accidents resulted from high speeds in roads in Saudi Arabia was also studied [16]. An assessment tool is developed to improve the safety performance for creating scores and weights of various accidents in construction projects [17]. Finally, a study inspected

the vehicles influence on the soil of roads in Saudi Arabia [18].

Furthermore, it should be referred to some studies with a relation to factors, barriers, challenges and techniques control them in Saudi Arabia civil engineering projects. The challenges for managing waste materials resulted from construction and destruction in Saudi Arabia was studied [19]. A new approach was introduced to determine the effects of on-site delays in Saudi public construction projects and categorized based on different tendering stages [20]. The gap of understanding factors impact can be determined without seeing the relations of these factors on public–private partnership using a new assessment method [21]. The organizational participation of employees in Saudi contracting firms was examined through studying a sample of contracting firms [22]. An economic model is developed using the smart grid techniques based on cost-benefit s of the supplementing the electricity substructure projects in Saudi Arabia [23]. Two structural quantitative and qualitative models were presented utilizing data concerning the effects on undesirable thinking on risk management [24]. Based on using the cumulative distribution curves, a new method was introduced and assessment risk impact [25]. The method was verified by combining qualitative and quantitative analyses using risk components, risk breakdown structure, AHP. A system for controlling factors affecting project delivery was constructed to be suitable for developed countries [26]. Last of all, The relation between factors and accidents in construction projects was studied for the purpose of minimizing the chance of fatalities where an accident is inescapable [27].

II. Research Objectives

The main objective of the current research is to develop a new technique using limited data for assessing the factors controlling the quality and applying it in Saudi Arabia roadways projects. The application of the technique is based on combining the possibility of occurrence with the influence of each factor.

III. Factors Controlling Quality in Roadways

Factors identification means classifying most important causes of factors controlling a certain objective in a project such as project quality. One probable method of considering and organizing the factors that harm any project is joining the project general system with the project activities which can be represented in the form of Work Breakdown Structure (WBS). WBS can help in the assessment of activities by dividing the project structure to smaller activities in many levels. It also can support the documentation of factors [28]. The aim of this step in any project is to precisely evaluation the project's budget and examine associations among cost entries in the project. Many factors affecting projects objectives such as cost, time and quality were collected and can be applied to quality in all construction projects types [29]. The identified factors will be utilized in this study to evaluate their qualitative effects on the quality of Saudi Arabian roadways projects.

IV. Data Collection Methodology

Once there is a shortage of accessible ordered data associated to the possibility of occurrence of the factors controlling the quality of the Saudi Arabian roadways' projects, a questionnaire was considered based on many factors that control roadways projects to obtain data about the possibility and influences of the identified factors on the quality. The questionnaire technique is suitable in this case and considered commonly used in general and project management [30]. Direct distribution through meetings was used in gathering questionnaire responses to stimulate experts, confirm and improve the replies [31]. The introduced questionnaires were used with the main three associates in the roadway's projects (owners or their representatives of the roadways projects, consultants' engineers, and contractors who executing roadways projects in Saudi Arabia).

4.1 Field Survey Analysis

125 questionnaire documents were introduced and the total number of experts contributing in these data survey was 81 experts. Out of 48 questionnaire documents were recognized with contractors the received responses were 37, while 24 responses were received from 34 consultants. In case of owners, 20 responses were got out of 43 as summarized in table (1). The response rates that got due to analysis of questionnaires for different experts' groups were 77% for contractors, 70.5% for consultants and 46.5% owners. Furthermore, the replies rate was 64.8%. on the other hand, the maximum frequency value was for contractors represented by a percentage of 45.7% while the consultants occupied the second rank with a percentage of 29.6%. finally, the lowest frequency was represented by owners with a percentage of 24.7%.

Table 1: Return Rates and Frequency of Participation in the Conducted field Survey

Experts	Owner	Contractor	Consultant	Total
Distributed Questionnaires	43	48	34	125
Replies received	20	37	24	81
Replies rate (%)	46.5%	77%	70.5%	64.8%
Rate of participation	24.7%	45.7%	29.6%	100%

4.2 Years of Experiences

The experts' experiences specify the grade of consistency of the collected data introduced. Opportunely, more than 30 % of the experts who contributed in data collection completed more than 20 years of experiences, which improve the consistency of the data collected due to reliable and long number of experience years in the field roadways projects in Saudi Arabia. For confirming the reasonability of the questionnaires results, responses from experts with fewer than 5 years of experiences were cancelled. It is clear that a from table (2), the percentage of the experts who have experiences around 15-20 years is (26 %). On the other hand, the rate of experts with experiences between 10 to 15 years represented 22.2 % from total experts. However, the remaining of them (21%) have between 5-10 years of associated experiences. If the medium of execution experiences for all experts is determined in the roadways' projects in Saudi Arabia, it will be found about 17 years. Therefore, the current replies can be taken to represent successfully the real condition in the roadways' projects in Saudi Arabia.

Table 2: No. of Experiences Years for the Experts

Experiences Years	5:10 years	10:15 years	15:20 years	Greater than 20 years	Total
No of experts	17	18	21	25	81
Percentage from sample	21%	22.2%	26%	30.8%	100.0%

4.3 Agreement analysis

To simplify analyzing of the field survey results, it is difficult to separate the experts three groups results in results analysis stage. The familiar Ranking agreement factor and percentage agreement test was suggested to determine the level of agreements amongst the experts' groups (owners, consultants, and contractors) or not. This test is important to develop the analysis in case of high agreement based on the average among the three experts' groups.

Two indices in this test are used as follows: 1) Rank Agreement Factor (RAF), 2) Percentage of Agreement Factor (PAF). These indices were calculated for the purpose of rating the all identified factors controlling quality taking into account their possibility of occurrence and their influences on quality in roadways projects in Saudi Arabia among experts groups [32], [33]. This analysis will introduce the absolute differences. For instance, and for any two expert groups, their agreement is considered high when the value of the absolute difference in rating equal to three. Generally, there will be no complete agreement. A small value for RAF index denotes to a high agreement between the two specified expert groups, whereas when the value equal to zero, this indicates a complete agreement. Moreover, the PAF value should exceed 50% to signify a satisfactory agreement for any two experts' groups. Table (3) summarizes the values of RAF and PAF.

Table 3: Agreements Indices for Different Pairs of Expert Groups

Expert Group	Possibility		Influence on quality	
	RAF	PAF	RAF	PAF
Contractors and Owners	12.10	73.15	12.67	69.17
Contractors and Consultants	13.16	63.89	12.91	55.24
Owners and Consultants	11.35	73.55	10.98	77.19

Regarding Table (3) summary, it can be obviously realized that the agreements percentages of PAF exceed the half, which signify a satisfactory coinciding among experts' sets. The possibility percentage of agreement ranged from 73.55% to 63.89 %. In case of percentage of agreement, an adjacent agreement among all experts' sets was found due to their replies of the possibility of occurrences. On the other hand, a closer coinciding due to replies in case of both consultants and owners. The identified factors that denoted to importance, the higher value of RAF is for case of consultants and contractors. The RAF minimum values are (11.35 and 10.98) which refer to low agreements between consultants and owners for both possibility and influence on quality respectively. Lastly, if the agreements for all experts' sets are compared in all cases, the maximum agreement is in case consultants and owners according to high values of PAF as well as RAF low values.

Once the results of agreement test represented high values among all experts' groups in ordering, the new technique can represent the possibility of occurrence and the influence on the quality for all identified factors based on the previous analysis results for total replies.

V. Fuzzy Assessment Technique for Quality (*FATQ*)

Fuzzy logic tool was used in developing many evaluation techniques in construction projects either qualitative or quantitative. A model for evaluating barriers affecting tunnel construction operations stages is presented based on fuzzy set theory [34]. A three-stage approach based also on the fuzzy principles is proposed to cope with the risky projects [35]. The cost overrun due to challenges was established and the statistical properties were

explored using a large number of risk paths which can be blocked by preventing the cost overrun with a large total degree [36]. The results demonstrated that the construction stage was the stage most susceptible to challenges, followed by the post-construction and pre-construction stages.

There are limited techniques for evaluation and assessment roadways construction [37]. The main goal of the planned technique is evaluating the factors which control the quality objective in the roadway's projects in a satisfactory and suitable method. The technique relies on associating the possibility of occurrence for a certain factor and its influence on the quality of roadways projects.

The inputs utilized in this technique which in a form of crisps are through two indices: possibility index (P), and influence index for quality (IQ). For evaluating the factors controlling quality, a proposed index based on fuzzy tool is introduced (fuzzy index for quality (FQ)). This index represents the importance or the severity of any identified factor to evaluate the quality in roadways projects. A flow chart in Figure (1) declares the proposed technique.

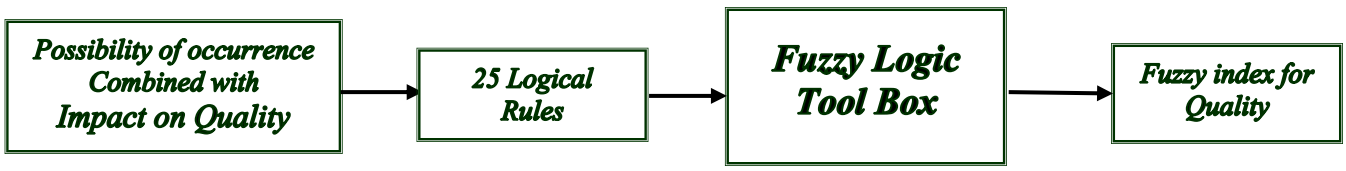

Figure 1: A flowchart Explaining the Proposed Technique

5.1 Membership functions

The fuzziness grade of linguistic terms can be signified by the membership function which is well-known to represent a mathematical value for all terms [3]. Any membership function recognizes the variety of input magnitude that matches to a specified term.

The proposed membership function in the *FATQ* is the triangle form to be used in expressing input and output terms characteristics (see Figure (2)). The triangular shape was previously used in several assessing tools through evaluating many phases in various civil engineering projects as well as it was selected as a familiar function in may previously studies. For examples, this function was introduced in a research that introduced a tool for evaluating factors based on the cause and effect diagrams technique [38]. Furthermore, it was utilized in evaluating the cost increase in international civil engineering projects [39]. Lastly, a study for choosing planning and design alternatives in public office buildings used the same function shape [40].

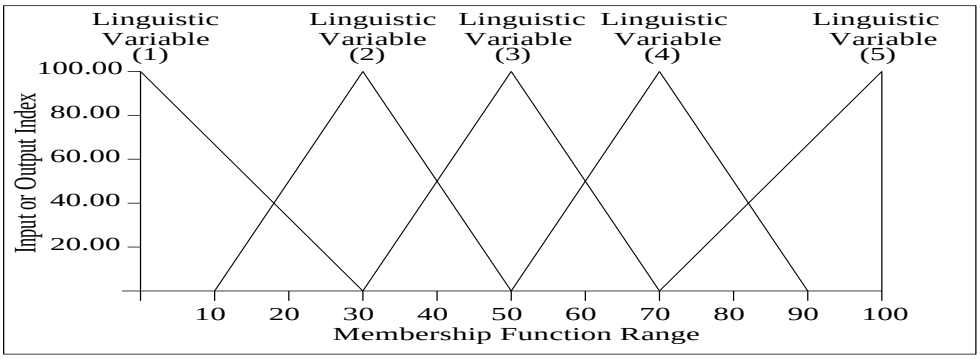

Figure 2: The Proposed Membership Function

The linguistics was used in the proposed technique as a very important advantage in the fuzzy set theory. In the proposed technique FATQ, the linguistics were used as the labels presented in the questionnaire. The fuzzy label for the possibility of occurrence for any factor are ranged between "very low" to "very high" as appeared in Figure (2). Each proposed term is related to a certain fuzzy group. The membership function assessment can be confirmed using two tests based on the overlap ratio parameter and overlap robustness parameter [41].

5.2 Logical Rules in the FATQ

Fuzzy logic always depends on using many logical rules through pointing the relation among linguistic variables through creating many rules (if-then rules). Any fuzzy group comprises both an antecedent and a consequent that contains fuzzy terms which can be represented by statements that connect the linguistics by operators. The logical rules use small numbers between the exact logic (zero: one). Correspondingly it contains many processes for using logical rules parameters such as (and, or, if, then) to represent the proposed rules.

The parameter "and" is proposed to be used in the proposed technique. It is utilized to associate the proposed linguistic terms. The planned rules in the proposed FATQ technique are presented in a membership function form using linguistics as explained before. The assessment of factors will be calculating a value based on the relation of possibility and influence. So, the association in the current technique includes two input terms and one output which will be denoted through 25 logical rules in inputs (factor possibility of occurrence and influence).

The association between inputs and the output terms is formulated using logical rules. Here is an example for such rules:

If the possibility of occurrence for a factor and influence of the same factor on quality then the importance of the factor due to quality of roadways projects

The changing values for inputs (*P*, *IQ*) and the output (*FQ) include many relations* which can be signified by means of fuzzy associative memories (FAMs) and the interrelationships in the FAMs [38], [42]. Table (4) introduces a matrix summarizes the proposed rules.

Table 4 : The Fuzzy Associative Memories of the Fuzzy Technique

Scale		Impact Index				
		VL	L	M	H	VH
Possibility Index	VL	VL	VL	L	L	M
	L	VL	L	L	M	M
	M	L	L	M	M	H
	H	L	M	M	H	VH
	VH	M	M	H	VH	VH
Very Low (VL) - Low (L) -Medium (M)-High (H)-Very High (VH)						

Using the proposed technique on MATLAB software, and after identifying the two input parameters (the

possibility and the influence) through the proposed logical rules (25 proposed logical rules), the output parameter can be determined in the form of factor importance for quality (FQ).

VI. Key Factors affecting quality due to FQ

As a qualitative analysis, there are many key factors affecting quality of roadways have an important variance according to the possibility of occurrence or their influence on quality. The planned technique presented a moral method for associating the effects of each factor by combining the effects of the possibility and influence. As appeared in Table (5), the ranking of the high ranked ten factors due to their FQ are arranged. The Change order due to owner new requirements factor was with a greatest significant factor due to its combined effect on the quality of Saudi Arabian roadways projects. Subcontractors Problems and Instability factor occupies in the second position in ordering due to FQ value, while the Delays due to Consultants and Owner representative and Contract disputes factor occupies the third and fourth orders correspondingly.

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

Factors	Rank due to *FQ*
Change order due to owner new requirements	1
Subcontractors Problems and Instability	2
Delays due to Consultants and Owner representative	3
Contract disputes	4
Unexpected site conditions	5
Design problems	6
Unskilled workers	7
Problems in accessing site	8
Delays in approvals from	9
Variations between Bidding BOQ and actual quantities	10

VII. Conclusions

In this paper, a new technique (FATQ) was presented and can be used in evaluating factors which have many barriers on the quality of roadways projects in Saudi Arabia. Using a designed questionnaire as field survey for data collection, the study identified and evaluated many expected factors controlling the quality in the execution of roadways projects in Saudi Arabia. The results of statistical tests revealed that there is an agreement among the experts' groups for evaluating the factors affecting the quality of roadways in Saudi Arabia. Consequently, formulation of the proposed technique followed the concept of using the mean values for the analyzed data of all experts' groups.

A new index was provided by the new proposed technique for the purpose of evaluating the factors that probably affect the quality in Saudi Arabia roadways projects. The technique depended on combining many characteristics for the factors including possibility of occurrence and the influence on highways projects quality utilizing the principles of fuzzy technique. The proposed index signified the value in addition to a rank for each identified factor which control the quality. The technique was assessed using the results from analyzing the questionnaire survey based on many factors controlling quality of the roadways' projects in Saudi Arabia. The technique can be considered important for other types of civil projects due to its flexibility and ease of modification for other types of projects or countries. The technique permits evaluating most factors categories which may affect civil engineering projects.

The results from implementing the technique specified that "Change order due to owner new requirements", "Subcontractors Problems and Instability", "Delays due to Consultants and Owner representative", and "Contract disputes" are considered the high-classified factors controlling quality of the roadways projects in Saudi Arabia. The study outcome introduces a complete figure to the Saudi Arabia government and companies which plan to execute their investments in roadways projects in

Saudi Arabia. The results aid them producing a complete thoughtful of the factors controlling quality in the Saudi Arabia roadways construction industry. Such considerate is very significant for applying further actual measures to ensure the right way of upcoming progress as well as producing a further suitable market for investments in roadways projects in Saudi Arabia.

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