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Fuzzy Assessment of Factors Influencing Quality Level of Highway Projects

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Abstract: A construction project such as highway comprises two distinct phases: preconstruction and construction. During these phases several factors are particularly noteworthy because of their significant impacts on the quality. As a result, the construction projects may be exposed to quality shortfalls. This paper aims at identifying the factors that may affect the quality of highway infrastructure projects in Egypt and determining their effectiveness degree through the application of fuzzy triangular approach. Using a detailed literature review, 39 factors have been identified to have an effect on the quality of the highway projects. A Pareto analysis shows that the first thirty factors contribute 80.249% of the weight of all the factors. The analysis of the collected questionnaires as perceived by the contracting engineers using the fuzzy approach reveals that availability of experienced staff in the owner's and contractor's teams during the project execution, asphalt quality and type used in the construction process, availability of the specified materials quality, pavement is not designed according to regional conditions (e.g. soil type -temperature - traffic volume) and design errors arising from inadequate engineer assumptions and inaccurate data are the major causal factors affecting the quality of the highway construction projects in Egypt.

Keywords: Fuzzy Approach, Quality, Highway Construction Projects, Management, Questionnaire Survey

1. Introduction

As mentioned in the National Cooperative Highway Research Program (NCHRP) report No. 626 [1], the pavement construction quality had been defined as "a tool or mean used by the owner and contractor to ensure that the desired results are obtained to produce high - quality and long- life pavements". Furthermore, it has been considered as a major factor in determining how well a pavement will perform under traffic loading and when subjected to environmental influences [2]. The quality and durability of our highways have always been a major concern to highway engineers and contractors as well as to top state highway agency [3]. This concern for the quality is to set forth the function of road construction quality which is to assure that roads are constructed in accordance with approved plans and specifications by the most economical, efficient and safe method [4]. Nowadays there are several reasons for ensuring the quality of a product however, the main reason is money. In highway construction industry, the contractors earn more money when producing a good quality product while the highway agencies save more money in future maintenance costs if the quality is built into the pavement [5].

The main benefits of achieving quality through the pavement construction processes are as following [6]:

- Reducing cost and time analysis because repeated effort is not needed.
- Reducing the cost of maintenance, reconstruction and repairing due to the reducing of pavement distresses.
- Increasing the services life cycle of the highway.
- Increasing the economic growth because the lower level of quality leads to additional repair and maintenance processes which delay traffic flow and transportations, causing increasing in losses and slowing down of the economic growth.
- Increasing the safety factor on the highway and thus reducing the rate of accidents.
- Improving agency decision making to be more effective and consistent.

2. Problem Statement and Objectives

Quality shortfalls and short-term pavement performance problems have been noted on several highways in Egypt during the past ten years. Several factors have been suggested to analysis the causes of this sudden change in highway infrastructure quality performance. Therefore, it is necessary to exert the utmost effort to accomplish a study on the quality of highway projects in Egypt by addressing the following issues:

1) Identifying the factors which may affect the quality of the constructed pavement.
2) Measuring the effectiveness degree of the identified factors and evaluate their relative importance on the quality performance of the constructed highway projects in Egypt.
3) Suggesting recommendations to the stakeholders of highway projects in Egypt in order to overcome the negative impacts of the factors which may lead to quality construction defects.

3. Methodology of Study

In order to achieve the desired objectives, the study framework involves ten stages. The sequence of such stages is presented in Fig.1.

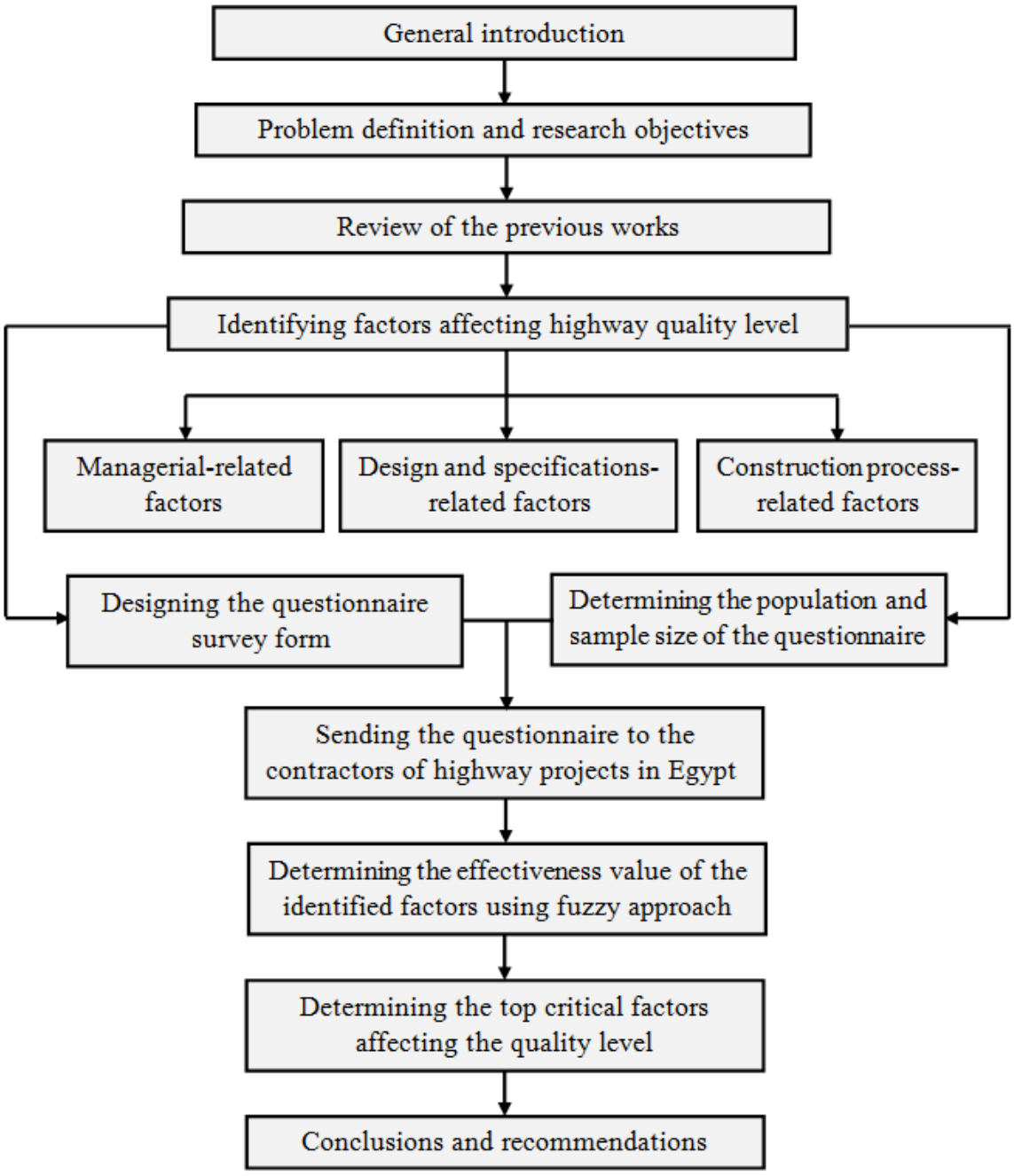

Figure 1. *The sequence of the research stages.*

3.1. Identifying Factors Influencing Quality Level

In the present study 39 factors have been identified to have an effect on the quality of the highway projects. Furthermore, the identified factors have been classified into three groups as follow: group (1) managerial-related factors, group (2) design and specification-related factors and group (3) construction process-related factors. Every group includes 13 factors. Table 1 shows the identified factors and their related groups.

Table 1. *Factors influencing quality level of highway projects.*

Sr.	Effective Factor
1	Group (1): Managerial-Related Factors
F1.1	Clarity of responsibilities and roles for each one of the owner, consultant and contractor
F1.2	Develop a clear and detailed program for quality management to be adhered by the owner, consultant and contractor
F1.3	Efficiency of the owner's inspection team
F1.4	Assignment of quality control responsibility to the consultant
F1.5	Technical assessment of the contractor during the bidding process
F1.6	Selection of the lowest bidder to construct the project
F1.7	Contractor's past experience
F1.8	Contractor's financial status during the project execution
F1.9	Amount of work sub-contracted
F1.10	Contractor's labors and equipments capability
F1.11	Cost escalation of resources (materials, labors and equipments) needed to achieve the required quality level
F1.12	Unavailability of financial incentive to the contractor to produce higher level of quality
F1.13	Delay in contactor progress payment
2	Group (2): Design and Specifications-Related Factors
F2.1	Pavement is not designed according to the regional conditions (e.g. soil type -temperature - traffic volume)
F2.2	Design errors arising from inadequate engineer assumptions and inaccurate data
F2.3	Insufficient owner involvement during the design phase (design evaluation, review and updating design)
F2.4	Accuracy of investigation performed on soil type encountered
F2.5	Accuracy of data related to traffic volume, composition and expected growth
F2.6	Use construction materials suitable for climate (temperature)
F2.7	Clarity and accuracy of specifications in relation to aggregates quality and gradation
F2.8	Clarity and accuracy of specifications in relation to asphalt quality and type
F2.9	Clarity and accuracy of specifications in relation to the required compaction level
F2.10	Over-specifying of materials and equipments to be used and construction method to be followed
F2.11	Limitation on materials sources, equipments type and construction method imposed by specifications
F2.12	Job mix formula type used to produce asphalt mixture (open graded- dense graded…etc)
F2.13	Asphalt mixture properties (e.g. stability-durability-workability)
3	Group (3): Construction Process-Related Factors
F3.1	Availability of experienced staff in the owner's and contractor's teams during the project execution
F3.2	Availability of the specified materials quality
F3.3	Asphalt quality and type used in the construction process
F3.4	Aggregates quality used in the construction process (e.g. gradation, shape, type)
F3.5	Variation in aggregates gradation in stockpiles, mixing, transportation and placement operation
F3.6	Variation in asphalt content during mixture operation
F3.7	Amount of filler materials in the mixture
F3.8	Continuous changing in mix design due to change in the nature and source of materials during construction phase
F3.9	The use of marginal materials in pavement constructed in regions of hot climate and heavy loading traffic conditions
F3.10	Condition of road bed soil
F3.11	Uniformity of mixture placement and compaction operations constructed in regions of hot climate and heavy loading traffic conditions
F3.12	Compacting pattern used to achieve the desired pavement density
F3.13	Paver and roller mechanical condition and type

3.2. Questionnaire Population and Sample Size

After the factors which may affect the quality performance of highway projects have been identified, a questionnaire has been designed in order to determine the effectiveness degree of the identified factors on the level of quality. The designed questionnaire consists of two parts. Part one includes personal information about the respondents such as his/ her name (optional) and relevant working experience, while the second part lists the 39 factors that influence the highway quality performance. For each factor, the respondents have to choose one out of the four possible answers representing varying degrees of effect on a scale of 1 to 4. A response of (1) means the factor is ineffective, (2) means the factor has medium effect, (3) means the factor is effective and (4) means the factor is very effective.

The target population of the designed questionnaire are contracting companies specialized in the construction of highway projects in Egypt. The available population of the contracting companies of highways in Egypt was 2082 companies which were current members of the Egyptian Federation for Construction and Building Contractors (EFCBC) within all grades during conducting this research. Therefore, a systematic random sample has been selected to

ensure a representative sample of all targeted respondents using Equation 1 [7]:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \quad (1)$$

Where n, n_0 and N represent the sample size of the limited, unlimited and available population, respectively. While, n_0 is estimated by the following Equation2:

$$n_0 = \frac{Z^2 pq}{e^2} \quad (2)$$

Where Z is the statistical value for the confidence level, p is the value of the population proportion which is being estimated, q=1-p and e is the desired level of precision. In the present research, a confidence level 90% is assumed thus Z=1.65 from normality tables, p = 0.5 and e = ±10%. By substituting of Z, p, q and e in Equation 2, the unlimited sample size of the population n_0 is 69 contracting companies. Consequently, substituting about n_0 and N in Equation 1, the required representative limited sample size n is 67 contracting companies. Based on the result of Equation 1, a total of 67 construction companies in Egypt were surveyed as a sample representing the available population of 2082 construction companies. The total number of completed questionnaires obtained from the 67 surveyed construction companies was 56 respondents.

3.3. Theory of Fuzzy Approach

The concept of fuzzy logic was first introduced in 1965 by Zadeh in his seminal paper on fuzzy sets [8]. Since then, research on fuzzy set has expanded to cover a wide range of disciplines and applications [9]. A fuzzy set approach is useful for uncertainty analysis where a probabilistic data base is not available and/or when (interval) values of input variables are uncertain [10]. The fuzzy set approach has been widely applied to represent the uncertainties of real-life situations [11]. Fuzziness represents situations where membership in sets cannot be defined on a yes/no basis because the boundaries of the sets are vague. The central concept of fuzzy set theory is the membership function, which represents numerically the degree to which an element belongs to a set [12].

Furthermore, the effectiveness of fuzzy sets depends on the construction of appropriate membership functions [13]. A membership function (MFs) is usually restricted to a certain class of functions that can be specified with only few parameters. The most well-known are triangular, trapezoidal and Gaussian as shown in Fig. 2 [14]. In this paper, in order to specify the effectiveness value of the factors influencing the quality performance on the basis of contractors' perspective, a triangle membership function has been suggested. The next sections will describe with illustrative example the steps followed to determine the fuzzy effectiveness value of the identified factors.

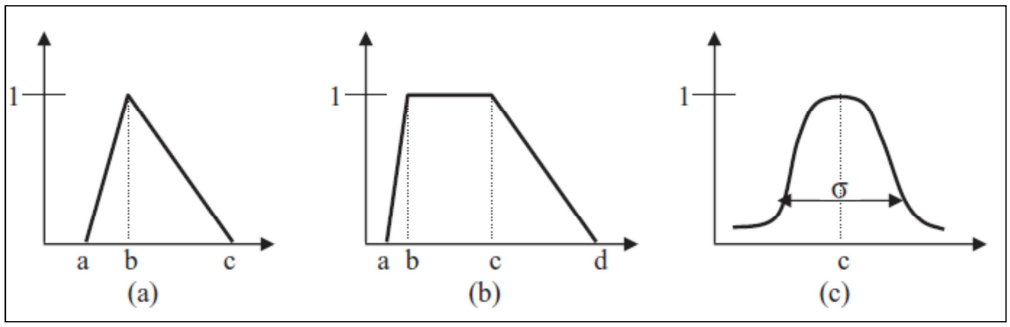

Figure 2. *Most commonly used shapes for membership functions. (a) Triangular, (b) Trapezoidal and (c) Gaussian [14].*

3.4. Triangular Fuzzy Membership Function

This section presents an illustrative example for the steps followed to determine the effectiveness value of the factors influencing the quality level according to the viewpoints of the contractors of highway projects in Egypt. These steps are:

1) Each factor will be fuzzified according to its weighted degree of severity effect which received from questionnaire responses.
2) Determine the minimum, medium and maximum effectiveness value of each factor.
3) Determine the membership of each effect according to its weighted degree of severity effect.
4) Forming a triangular membership function of each factor.
5) Ranking the factors according to its medium effectiveness value.

The following is an example for illustrating the previous steps. For instance, factor No. 3.1 "availability of experience staff in the owner and contractor team during the project execution" which has been fuzzified by the contractors of highways in Egypt as follow. The responses related to this factor from the respondents are 50 for very effective, 6 for effective, 0 for medium effect and 0 for ineffective. Accordingly, the weighted degrees of severity effect are: [(50x4)/ (4x56)] x100 =89.29%, [(6x3)/ (4x56)] x100= 8.03%, [(0x2)/ (4x56)] x100= 0.0% and [(0x1)/ (4x56)] x 100=0.0% for (4/4)=1, (3/4)=0.75, (2/4)=0.50 and (1/4)=0.25 memberships respectively.

The next step is to determine the medium effect for factor No. 3.1 as follow: medium effect= (89.29+8.03+0+0)/4=

24.33 %. Fig. 3 shows the minimum, medium and maximum effect for factor No. 3.1. According Fig.3, the minimum value among participants (contractors) is 0.0%, the medium value is 24.33% and the maximum is 89.29%. At the end minimum, maximum and medium effect for each factor is calculated from the perspective of involved respondents and the process of ranking will be applied to these factors by comparing their medium effect.

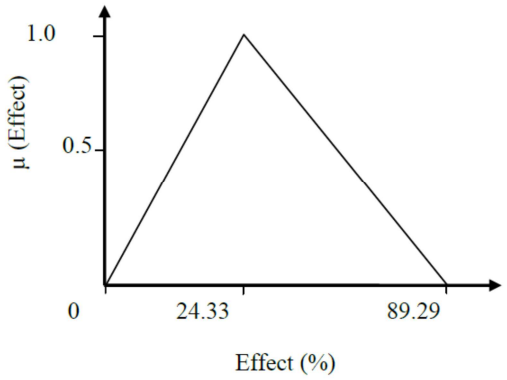

Figure 3. *Fuzzy effectiveness values of factor No. 3.1 on quality level.*

4. Results and Discussions

The result of the questionnaire is shown in Figs. 4, 5 and 6. The factors that are believed to affect highway quality performances are listed with their medium fuzzy effect. The three groups of factors (managerial, design and specifications and construction process) have been discussed in the following paragraphs.

4.1. Managerial-Related Factors

Fig. 4 shows the medium fuzzy effect of 13 factors of the managerial group on quality level from the viewpoints of contractors in Egypt. According to Fig. 4, the contractors of highway projects in Egypt determine that the quality of an asphalt concrete pavement is affected to a high degree by factor No. 1.10 "contractor's labors and equipments capability" with medium effectiveness value = 22.99%. This is due to the major task of the contractors is to assemble and allocate the resources of labors, equipments and materials to the project in order to achieve completion at maximum efficiency in terms of time, quality and cost [15]. The second important factor which also has an effect of the quality is factor No. 1.1"clarity of responsibilities and roles for each one of the owner, consultant and contractor". Construction of highway project includes many teams such as contractors, subcontractors, owners and others, in such case it is essential to detail and describe in a clear manner the roles, responsibilities and authorities for each member will participate in the execution of the project through the application of program for management the quality within the contract documents. Consequently, misunderstanding, conflicts and disputes between project stakeholders will be minimized.

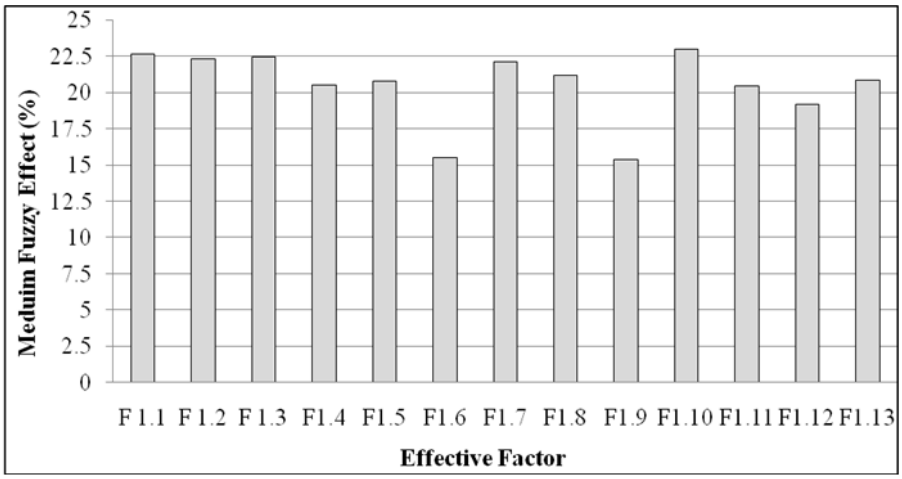

Figure 4. *Medium fuzzy effect of factors of managerial group on quality level in highway construction projects.*

Furthermore, the contractors of highway projects in Egypt classify factor No. 1.3 "efficiency of the owner's inspection team" as the third factor influencing the quality of the constructed pavement with medium effectiveness value = 22.43%. Similarly, Jha and Iyer [16] achieved the same result that, the owners play an important role in achieving the desired quality level. Moreover, Barnes [17] recognized that having the client's inspector's work with the contractor to establish good quality control procedures before the work is done is much more effective than walking around after. On the other hand, factor No. 1.9 "amount of work sub-contracted" has the lowest fuzzy effectiveness value = 15.40% on the quality level. The reason of this result is due to in the majority of highway projects in Egypt; the amount of work sub-contracted is very limited and only confined in the supplies of the construction materials such as different types of aggregates and bitumen materials. Moreover, before the usage of these materials in the construction process, the owner asks the contractor to perform the required tests on these materials to make sure that these materials is in consistence with the specifications of the project.

4.2. Design and Specifications-Related Factors

Figure 5 shows the medium fuzzy effect of factors of design and specifications group on quality level as perceived by the contractors of highway projects in Egypt. Referring to Fig. 5, factor No. 2.1 "pavement is not designed according to the regional conditions (e.g. soil type - temperature - traffic volume)" has been ranked as the first factor affecting the quality of the pavement. The design of flexible pavement is the process of selecting the pavement layer types and thicknesses in order to withstand the expected traffic loads in a cost-effective manner. This process involves studies of soils and paving materials, their behavior under loads and the development of a pavement section to carry loads under all climatic conditions [18]. Therefore, in order to provide an adequate pavement performance for the required design life, the pavement cross section properties (materials types and thickness) must be determined with respect to the actual and anticipated traffic volume, the prevailing climatic conditions in the construction site, project's soil type and reliable design procedures.

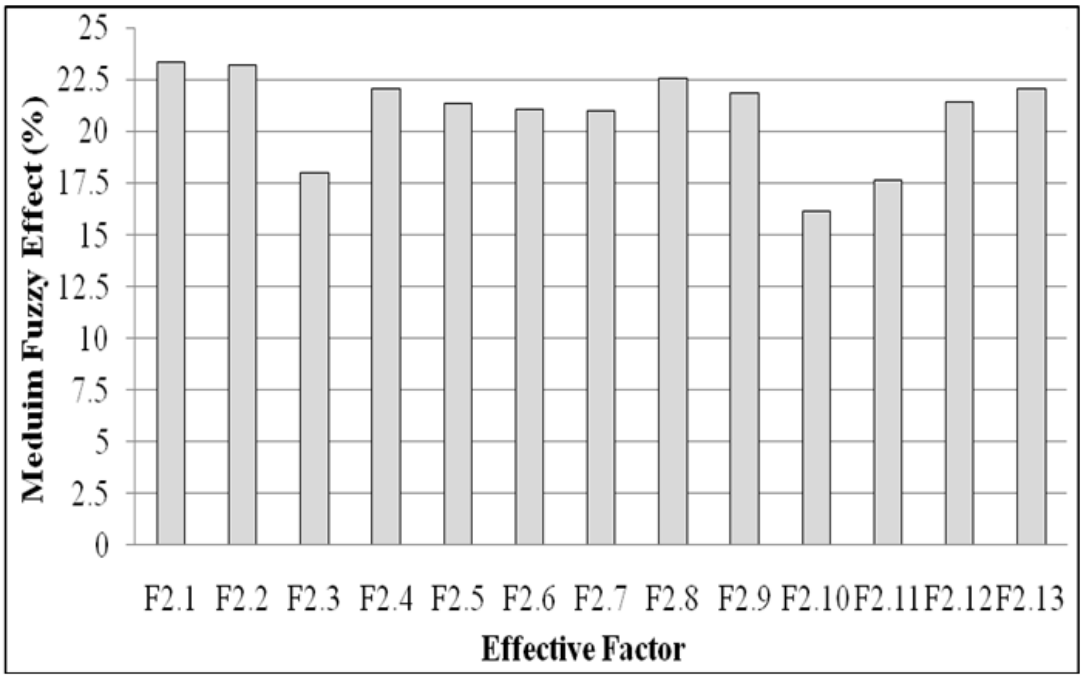

Figure 5. *Medium fuzzy effect of factors of design and specifications group on quality in highway construction projects.*

In addition, Fig. 5 shows that factor No. 2.2 "design errors arising from inadequate engineer assumptions and inaccurate data" has been ranked as the second factor affecting the highway quality. This is due to pavements are complicated physical structures responding in a complex way to the influence of many variables such as loading, environment, material properties and variability, construction quality…etc. [19]. These variables represent the inputs data to the design process. While, the output is to get suitable highway capable of withstanding the adverse impacts of the traffic volume and climate conditions without any failure during its design life. So, the inadequate engineer assumptions and inaccurate data will directly affect the end result of the highway.

The third factor affecting the quality from the contractors' perspective is factor No. 2.4 "accuracy of investigation performed on soil type encountered". The same finding has been found by Guyer[20] who noted that the subgrade provides a foundation for supporting the pavement structure. As a result, the required pavement thickness and the performance obtained from the pavement during its design life will depend largely upon the strength and uniformity of the subgrade. Therefore, insofar as is economically feasible a thorough investigation of the subgrade should be made so that the design and construction will ensure uniformity of support for the pavement structure and realization of the maximum strength potential for the particular subgrade soil type. Otherwise, factor No. 2.10 "over - specifying of materials and equipments to be used and construction method to be followed" has the lowest effectiveness value among the factors of design and specifications group. The result of Al Hassan [21] is in coincide with this finding which indicates that over-specifying and limitation on materials sources, equipments type and construction method imposed by specifications have a small effect on the pavement quality.

4.3. Construction Process-Related Factors

Fig. 6 shows the medium fuzzy effect of factors of construction group on the quality level. According to the contractors' perspective as presented in Figure 6, the quality of the constructed pavement is affected to a high degree by factor No. 3.1 "availability of experienced staff in the owner's and contractor's teams during the project execution". The availability of experienced engineers in the owner's and contractor's teams is essential to monitor and control over the

outcome of the project. For instances, the owner needs the experienced engineers to inspect the project's activities and make sure that the specifications of the contract are followed by the contractor's staff. While the contractor needs experienced engineers to manage these activities and achieve the client desire concerning the required quality. Consequently, it can be concluded that "project without experienced staff equals project without quality". Moreover, factors No. 3.3 "asphalt quality and type used in the construction process" has been classified as the second factor affecting the quality of the highway projects. Though, the coarse aggregates are the main load bearing component in a pavement, bitumen or asphalt also plays a vital role in distributing the traffic loads to the layers beneath [22]. In addition to being smooth, durable, safe and quiet, asphalt is the most versatile pavement material [23]. Bitumen can be termed as the building block of the pavements without which all the pavement materials would behave independently and thus will be deemed useless. Moreover, bitumen strongly binds and cements the whole mixture together without bringing about any positive or negative changes in their properties and also provides a smooth and leveled surface for the moving vehicles [22].

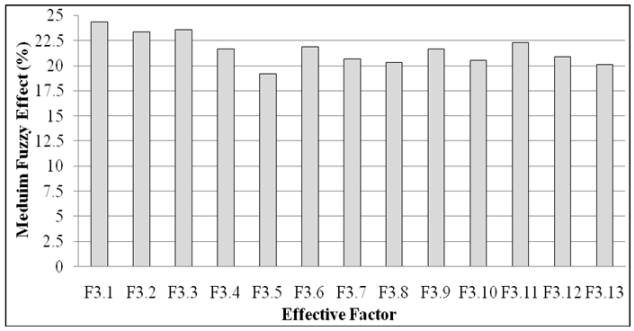

Figure 6. *Medium fuzzy effect of factors of construction process group on quality in highway construction project.*

According to Garber and Hole [24], the properties of the asphalt materials pertinent to pavement construction can be grouped under the following four headings: consistency, durability or resistance to weathering, rate of curing and resistance to water action. Quality of asphalt and its suitability for any given use are completely defined by these four properties. Moreover, the asphalt cement requirements include the asphalt content and the asphalt grade. The successful performance of asphalt requires the proper selection of these requirements. Therefore, it is necessary to closely control the asphalt content, grade and type in hot-mix asphalt mixes to obtain optimum serviceability and durability. On the other hand, factor No. 3.5 "variation in aggregates gradation in stockpiles, mixing, transportation and placement operation" has the smallest effect on the performance of the quality according to the respondents' point of view. This result does not reflect entirely the unimportance of the variation in aggregates gradation on the pavement performance, but illustrates that the quality from the viewpoint of the contractors is more influenced by other factors such as the experience of the staff in the owner and contractor team-work, quality and grade of asphalt.

4.4. Top Factors Influencing Quality of Highway Projects Performance

Fig. 7 shows the fuzzy average and accumulation effect of the factors influencing quality level of highway projects in Egypt according to the viewpoints of the respondents to the questionnaire survey. The analysis of this Figure presents that:

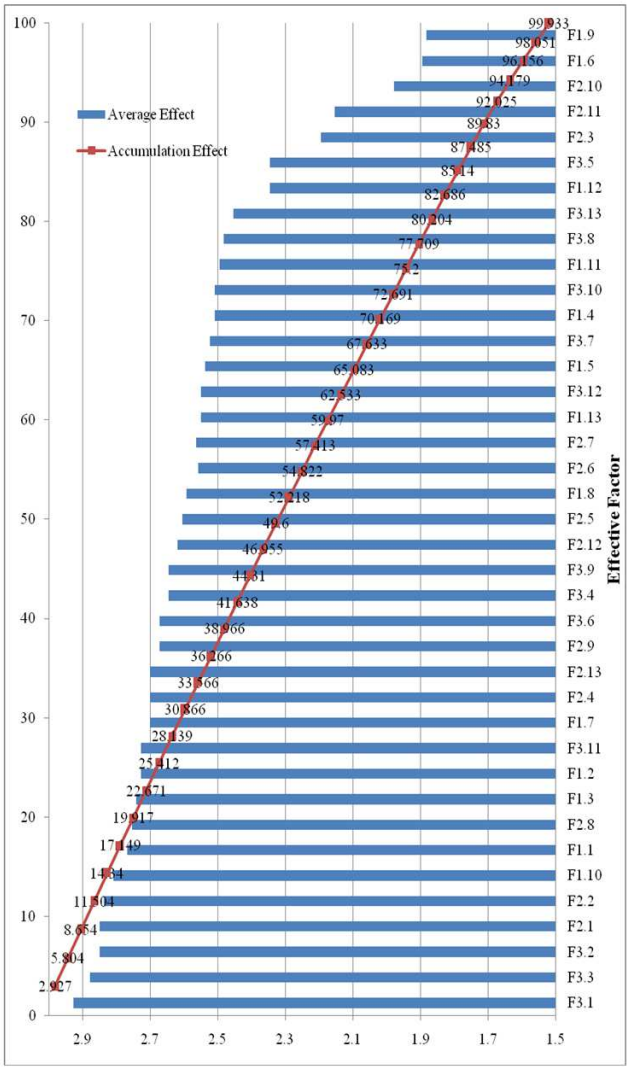

Figure 7. *Pareto's analysis of factors influencing quality level.*

- The most important factor affecting the quality level is factor No. 3.1 "availability of experienced staff in the owner's and contractor's teams during the project execution" followed by factor No. 3.3 "asphalt quality and type used in the construction process" with average effects = 2.972% and 2.877% respectively.
- The less influential factor affecting the quality level is factor No.1.9 "Amount of work sub-contracted" with an average effect = 1.882 % on the level of the quality.
- According to Pareto law, 20% of causes have 80 % of the effect [25]. Fig. 7 shows that 80% of reasons which

influencing the quality level in the Egyptian highway projects are due to 30 causes and more than 50% of them are due to only 18 causes. Therefore, Fig. 7 can be used in order to perform studies and represent solutions to obviate or decrease the reasons of the poor performance of the quality in highways network in Egypt.

5. Summary and Conclusions

This paper introduces 39 factors, which may affect the quality performance of highway projects. Furthermore, the effectiveness degree of the identified factors has been determined by distributing questionnaires to the contractors of highway projects in Egypt. Through the application of fuzzy triangular approach on the data which have been collected from the respondents to the questionnaire, it has been concluded that:

1. The key factor in controlling the constructed quality of the highway projects in Egypt is "availability of experienced staff in the owner's and contractor's teams during the project execution" with an average effect of 2.972% on the quality level.
2. Factors No. 3.3 "asphalt quality and type used in the construction process", No. 3.2 "availability of the specified materials quality", No. 2.1 "pavement is not designed according to the regional conditions (e.g. soil type -temperature - traffic volume)" and No. 2.2 "design errors arising from inadequate engineer assumptions and inaccurate data" are the major causal factors affecting the quality of the highway construction projects in Egypt.
3. The long-term performance of flexible pavement can be represented in equation form as follows "quality of highway=skilled staff + effective design + good construction practice".

Recommendations

According to the above-mentioned findings, the following points can be recommended in order to improve and control quality performance in highway infrastructure projects:

1. Quality is the responsibility of the owner, contactor, consultant and any one of their staff who may be involved. Thus, the roles and responsibilities of each party should be cleared and discussed at the beginning of the project and at a pre-activity meeting when an upcoming activity will impact more than one of the project teams.
2. The availability of experienced and efficient staff in the owner's, consultant's and contractor's teams is essential factor for monitoring and controlling over the outcome of the project and achieving the desired quality level.
3. All the stakeholders of highway projects in Egypt (owners, consultants and contractors) have to develop plans and programs for training their staff in order to improve their skills and qualifications through the presence of human resources department responsible for handling professionals and staff training.
4. Awarding the project to the lowest bid price has a severe effect on the delivery of the project. Accepting the lowest price is the basic cause of the project completion problems because very often lowering the price means lowering the quality. Furthermore, the lowest bidders are low qualified contractors with a shortage in resources and low capabilities. Therefore, it is recommended to improve the prequalification standards and awarding policy to control this problem.
5. Detailed and comprehensive site investigation should be done during the design phase in order to collect accurate data about the design parameters such as (soli type, temperature...etc). Furthermore, allow sufficient time for proper planning and design process will help the designers to avoid errors and omissions.

References

[1] Transportation Research Board Executive Committee, "NDT Technology for quality assurance of HMA pavement construction," NCHRP Report No. 626, 2009, Washington, D. C., USA.

[2] J. A. Deacon, C. Monismith, J. Harvey, and L. Popescu, "Pay factors for asphalt-concrete construction: effect of construction quality on agency costs," Technical Memorandum, TM-UCB-PRC-2001-1, Pavement Research Center, Institute of Transportation Studies, 2001, University of California, Berkeley, California, USA.

[3] S. P. La Hue, "Quality assurance and quality of construction," Quality Assurance in Pavement Construction, Ed. Allen, G. J., ASTM STP 709, Philadelphia,1980, USA, 3-10.

[4] BIAM "Construction quality," 57 BIAM Supplement No. 2, Bureau of Indian Affairs Manual, 2008, Washington, D. C, USA.

[5] S. Pathomvanich, "Assessment of the effectiveness of quality assurance construction specifications for asphaltic concrete pavement," PhD Thesis, Department of Civil and Coastal Engineering, 2000, Graduated School, Florida University, USA.

[6] H. F. Thurner, "Quality assurance and self-control in road construction, advanced measurement technology." Technical Paper, Geodynamic AB, Stockholm, 2001, Sweden, No. 11, 1-10.

[7] W. G. Cochran, "Sampling techniques,"3rd Edition, John Wiley and Sons, 1977, New York, USA.

[8] L. A. Zadah, "Fuzzy sets, "Information and Control, 1965, Vol. 8, No. 3, 338-353.

[9] H. Asmuni, " Fuzzy methodologies for automated university timetabling solution construction and evaluation," PhD Thesis, School of Computer Science, 2008, Faculty of Science,

[10] M. P. Jalal, P. Ghoddosi, and M. Hosseinalipour, "Development of a fuzzy risk assessment and contractual allocation model for Iran's dam construction projects," 1st International Conference on Construction in Developing Countries 2008, Karachi, Pakistan, 366-375.

[11] I. Bogardi, and A. Bardossy, "Regional management of an aquifer for mining under fuzzy environmental objectives," Water Resources Research, 1983, Vol. 19, No. 6, 1394-1402.

[12] J. Ganoulis, L. Duckstein, and I. I. Bogardi, "Risk analysis of water quantity and quality problems: the engineering approach," Water Resources Engineering Risk Assessment, Ed. Ganoulis, J., NATO ASI Series, Series G: Ecological Sciences, 1991, Vol. 29, 3-17.

[13] A. Burney, Z. Abbas, N. Mahmood, and Q. Arifeen, "Application of fuzzy rough temporal approach in patient data management (FRT-PDM)," International Journal of Computers, 2012, Vol. 6, No. 3, 149-157.

[14] M. Kantardzic, "Data mining: concepts, models, methods and algorithms.," 2nd Edition, John Wiley and Sons, Inc., 2011, Hoboken, New Jersey, USA.

[15] A. O. Omole," Causes of the high cost of building and civil engineering construction in Nigeria." The Nigerian Quantity Surveyor, 1986, (6) 1-2.

[16] K. N. Jha, and K. C. Iyer, "Critical factors affecting quality performance in construction projects," Total Quality Management and Business Excellence Journal, 2006, Vol. 17, No. 9, 1155-1170.

[17] M. Barnes, "Construction project management," International Journal of Project Management, 1988, Vol. 6, No. 2, 69-79.

[18] Transportation Advisory Board, "Pavement design: concepts & sections," Public Works Department, Engineering Services Division, 2010, Tulsa, Oklahoma, USA.

[19] F. Parker, and J. Song, "Evaluation of flexible pavement performance using LTTP data," Final Report Project No. 930-419, Highway Research Center, Herbert Engineering Center, 2002, Auburn University, Alabama, USA.

[20] J. P. Guyer, "Introduction to flexible pavement design," Course No: C02-015, Continuing Education and Development, Inc., 2009, New York, USA.

[21] M. S. Al-Hassan, "Factors affecting quality of pavement construction in Saudi Arabia," M. S. Thesis, Department of Construction Engineering and Management, College of Environmental Design, King Fahd University of Petroleum and Minerals, 1993, Saudi Arabia.

[22] H. Jamal, "Types and properties of bituminous materials," http://www.aboutcivil.org/importance-types-of-bituminous-materials.html,Accessed on October 2, 2014.

[23] NAPA, "Types of asphalt pavement," National Asphalt Pavement Association, Washington, 2016, D. C., USA.

[24] N. J. Garber, and L. A. Hoel, "Traffic and highway engineering," 4th Edition, SI Version, Cengage Learning, 2010, USA.

[25] E. Eraslan, and M. Kurt, "A fuzzy multi-criteria analysis approach for assessing the performance of modern manufacturing systems," Proceedings of the 35th International Conference on Computers and Industrial Engineering, Istanbul, 2005, Turkey, 605-610.