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On the quality of driven piles construction based on risk analysis

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Abstract

Driven Precast Reinforced Concrete Piles (DPRCP) is extensively used as a foundation for bridges constructed over canals in Egypt in order to avoid the diversion of water canals. The objectives of this research include identifying the main activities of DPRCP execution in the bridge-construction industry in Egypt and the risk factors affecting them. In addition, assessment of the effects of these risk factors on the quality of activities of DPRCP. Four activities are identified in order to execute the process of construction of DPRCP. These activities include: preparing and casting piles, positioning piles and steering the driving machine, handling piles, and driving piles. Thirty one risk factors affecting the DPRCP activities execution are identified. A survey was executed in Egypt concerning probabilities of occurrence of these factors and their impacts on the quality of activities of DPRCP. In addition, a new membership function is introduced to represent the quality of activities and used in a fuzzy model for factors assessment. Results showed that the proposed membership function can be used effectively to assess the quality of activities associated with the construction of DPRCP. A list of risk factors is highlighted to show the most critical risk factors that help in preparing the quality management plan for the upcoming similar projects. The gentile distribution of data obtained for the different activities proved that the investigated risk factors for the DPRCP in this study are significant.

Keywords: *Risk factors, Quality assessment, Driven precast concrete pile, Fuzzy model, Membership function.*

1. Introduction

Egypt has a large network of irrigation and drainage system in order to fulfill the requirements of agricultural activities. The majority of water canals in Egypt that they are located adjacent to roads, highways and railways and pass inside villages/towns. This causes a barrier for people to transport from side to another in villages/towns. Therefore, construction of a huge number of bridges over water canals to facilitate transportation of residents in such areas is needed. Due to the closeness of buildings and railways to water canals in Egypt, it is difficult to divert waterways during bridges construction. Subsequently, DPRCP is considered the appropriate foundation type used in bridge construction over canals in Egypt to avoid diversion of the pathway of water canals. Driven piles were used in the early times over the world as a way to support structures and they are commonly constructed from timber, precast concrete and steel [1].

The selection of piles material depends on the location and type of structure, the ground conditions, method of handling, and durability [1-3].

Generally, pile foundations can be classified into three categories when piles are used to reduce settlement based on their design [4]. These categories include large displacement piles, small displacement piles and replacement piles. The first two categories can be driven or jacked into the ground and thus displace the soil. This section presents a brief description for design, construction techniques and activities associated with driven piles. Design of driven piles to support loads is one of challenges meet the geotechnical engineer since there are many parameters control piles design. There are two ways for transferring loads from piles to soil, shaft friction and base resistance or end-bearing. The transferring of loads from pile to soil depends on type of soil, type of pile material, loads and type of loads. By knowing all these parameters, the carrying capacity of piles can be determined and the pile can be designed to resist the required loads safely [5]. Construction technique used for DPRCP includes preparation of concrete piles and installation of piles by driving. More attention should be given during the process of the installation of precast concrete piles to obtain straight piles with high quality to sustain the stresses developed during driving process. Consequently, attention has to be paid to improve the quality of bridges construction using DPRCP in Egypt. All these attentions were directed only to technical problems while, up to the authors' knowledge, there is no study dealing with the risk

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factors affecting the activities and quality for bridge construction using DPRCP in Egypt or throughout the world. As technical instructions are important in such projects, studying the activities controlling the quality of DPRCP is more important to meet the standards. It is important that it be evident, that there are limited studies available in literature focused on the quality of other types of piles construction [6-7].

To sum up, the activities of DPRCP execution in bridge construction faces many risk factors that control their quality. Consequently, in general this paper focuses on identification and assessment of risk factors affecting the quality of the investigated activities. These activities include preparing and casting the piles, positioning piles and steering the pilling machine, handling piles, and driving piles. While the specific objective of this research is to identify and explore the various components of risk factors affecting the activities of construction driving piles in bridges throughout the Egyptian context. This specific objective can be done throughout the following tasks: (1) Explore and identify the main activities during execution of DPRCP; (2) Present a general overview for the factors and their probabilities and impacts on the quality of DPRCP activities in Egypt; (3) Introduce and propose a suitable membership function, which can be used in defining risk factors affecting quality in construction projects; (4) Applying a fuzzy assessment model using the proposed membership function in order to highlight the most important of the risk factors; and (5) Introduce a recommendation for quality management plan that may be applied in upcoming projects based on the most significant and critical risk factors control the activities quality of DPRCP.

2. Research Methodology

Semi-structured interviews are introduced in this study to be executed by professionals in the field of DPRCP used in bridge construction in Egypt. The objective of these interviews is to identify the main activities and risk factors affecting each activity for these piles. The interviews are followed by conducting a questionnaire survey based on knowledge available from the professionals in different Egyptian cities. The objective of the questionnaire is to collect data that concerns the probability of occurrences and impacts of each factor on the quality of the associated activity.

Semi-structured interviews are conducted with a fairly open framework which allows for conversational and two-way communications. They can be used both to give and receive information. The main objective of these interviews in this research is to identify the main activities of DPRCP and risk factors affect each activity. Thirty two semi-structured interviews with professionals in the field of DPRCP used in bridge construction as well as literature surveys were conducted. Most of the interviewees were from the Ministry of Transportation and Ministry of Water Resources and Irrigation in Egypt since both organizations are responsible for management, planning and construction of these projects in Egypt. In addition, interviewees with some contractors who work in executing such projects were also considered. Before the interviews, authors prepared a list for common risk factors in construction projects to help the interviewees to add, subtract and modify of them. The interviews covered many Egyptian governments including Beni-Suef, Alfayoum, Minia, Sohag, Qena, Luxor, and Aswan.

3. Activities and Risk Factors

There are four identified activities associated with the construction and installation of DPRCP. These activities are: (A) preparing and casting the piles; (B) positioning piles and steering the pilling machine; (C) handling piles; and (D) driving piles. For each activity, there are many risk factors controlling the quality of activity and these factors are varying from activity to another based on the type of activity. For better illustrations, the risk factors control each activity are identified and described briefly as presented in Table 1. As presented in this table, it is clear that the activity D is controlled and identified with the maximum number of factors, which are eleven, compared to other activities. Increasing the number of factors for activity D is related to the difficulty of the driving process, since there are many factors control this process. It is important to evident that there are some risk factors affecting more than one activity. For example, the risk factor "extreme weather conditions and characteristics of the waterway section, such as channel width and water velocity" affect activities B and C. Also, the risk factor "lack of specialized laborers running machine" affect activities B and D.

Table1 Descriptions for risk factors control the executed activities for driven piles in Egypt

Activity (A): Preparing and Casting Piles
1. Using inappropriate tools (such as the type of casting mold)
2. Poor materials quality, for example the gravel gradation
3. Inappropriate casting method
4. No use for separation materials between piles during casting
5. Incorrect preparation and poor choice for casting and curing area
6. Poor curing for the precast piles
7. Weak connection between the pile reinforcement with the pile edge
8. Piles arrangement and number of piles in the casting and curing area
Activity (B): Positioning piles and Steering Pilling Machine
1. Using inappropriate surveying devices to steer the pilling machine
2.Difficulties of implementing marks to locate the pile over the water

3.Poor system of fixing pilling machine such as using buoy or temporary timber piles
4.Lack of specialized laborers running machine
5.Extreme weather conditions
6.Characteristics of the waterway section such as channel width and water velocity
Activity (C): Handling Pile
1. Handling the pile in an unsafe manner or from non-specific lifting places
2. Distance of transferring the pile from casting and curing area to the specified pile location
3. Lack of specialized equipment's
4. Inability of the pile to bear the stresses resulting from the handling process
5. Extreme weather conditions
6. Characteristics of the waterway section such as channel width and water velocity
Activity (D): Driving Pile
1. Lack in using new techniques in driving or in case of obstacles that constrain the driving process
2. Lack of specialized laborers running machine
3. Differences between soil boring report and the soil nature
4. The machine or the pile is not vertically
5. Non suitability of the hammer distance and driving rate for the pile
6. Collapsing of the pile head due to non-using a cushion to absorb the driving energy
7. Poor arrangement for piles precedence execution
8. Stopping during driving a certain pile
9. Environmental problems due to driving such as noise or steam
10. Problems due to site conditions such as railways adjacent the site
11. Lack of follow-up and slow decision during the process of driving

A questionnaire was designed based on the identified DPRCP activities and risk factors affecting them as presented in Table 1. The questionnaire was divided into two sections; the first is to know the general particulars of the respondents, and the second is to focus on the probability of occurrence and the impact of the risk factors on the quality of specific activity. The approach of the questionnaire is well-recognized and widely used in general management and project management research [8-10]. Face-to-face delivery was selected in order to motivate respondents, ensure the accuracy of answers and improve response rate as suggested in previous work [11]. The respondents were asked to choose one of seven levels for the probability of occurrence and impact of each risk factor on the quality of the activity. These levels ranged from the highest to the lowest. More details on these levels and how they were chosen for the questionnaires to suit the proposed membership function, which will be used in the assessment model, will be explained later. The response rates from the different groups were 59.5% from contractors, 57 % from consultants and owner representatives and the average response rate was found to be 58%. The percentage of respondents is presented in Table 2. The consultants and owner representatives give the highest frequency with 60% while 40% was found in the case of consultants. Table 3 represents an image of the strength of respondents' experience prior to indicating the degree of reliability of the data provided by participants. Fortunately, about 30 % of the professionals who participated in this survey have over 20 years of experience, which stresses 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 neglected. As shown in Table 3, it is obvious that 29% of the participants have an experience of 15-20 years. The frequency of respondents who have experience between 10 to 15 years is found to be 25.80 % of the total respondents, whereas, the rest of them, represented by 14.50 % had 5–10 years of relevant experience. The average working experience of all respondents was found 15.50 years in the field of PCDP construction, and thus the opinions are thought to reflect the real situation in this industry.

Table 2 Questionnaire return-rate and frequency of participation

Respondents	Contractor	Consultant/Owner representatives	Total
Number of questionnaires distributed	42	65	107
Number of responses received	25	37	62
Response rate, (%)	59.5%	57%	58%
Frequency of participation	40%	60%	100%

Table 3 Years of experience for respondents

Experience years	5-10 years	10-15 years	15-20 years	>20 years	Total
No. of respondents	9	16	18	19	62
Percent	14.52	25.81	29.03	30.65	100

4. Membership Functions and MF2 Verification

The developed Fuzzy Assessment Model for Quality (FAMQ) by Issa [12-13] was applied in this research in order to assess the factors controlling the quality of activities. This model was used successfully in the assessment of factors affecting quality in the construction industry. In this model, a triangle membership function was used as shown in Figure 1a and namely in this research (MF1). Besides, a new membership function is introduced in this research with another shape for triangles as presented in Figure 1b based on a previous work [14].

This is to evaluate the efficiency of a new membership compared to the results obtained from MF1. The new membership is namely in this research (MF2) and the linguistic variables for quality are defined in 7 levels as: The Highest (TH), Very High (VH), High (H), Medium (M), Low (L), Very low (VL) and The Lowest (TL). Each term can be represented by a suitable triangular fuzzy number for quality Q = {Q 1, Q 2, Q 3} as shown in Figure 1b. The corresponding fuzzy sets can be defined for the input and output Membership function as follows: The Lowest (0, 0, 20), Very low = (0,20,40), Low = (20,40,60), Medium = (40,60,70), High = (60,80,90), Very high = (70,90,100), and The highest (90,100,100). In this research, the FAMQ is modified using the proposed membership function (MF2) by rewriting the model. Assuming there is a relationship between the two inputs probability of occurrence for a certain risk factor and represented by its probability index (PI) while the impact of the same factor on a project quality is represented by its impact index for quality (IIQ). PI can be defined as an equation to assess or rank risk factors based on their probability of occurrence as identified by the participants. While IIQ can be defined as an equation to assess or rank risk factors based on their impact on the project quality as identified by the participants. More details about these parameters are presented in previous works [12-13].

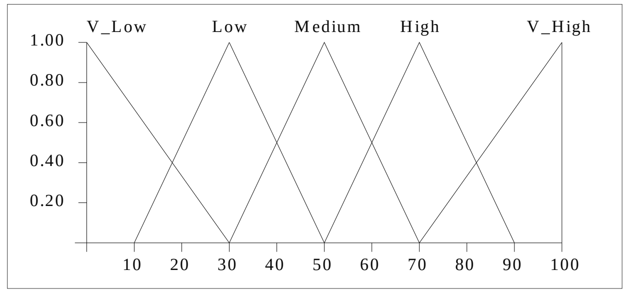


Fig. 1a The membership function used in FAMQ model, MF1 [10-11]

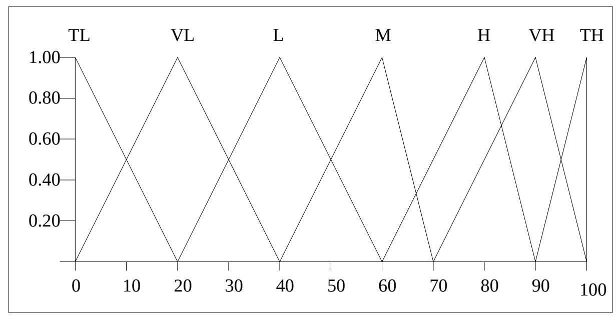


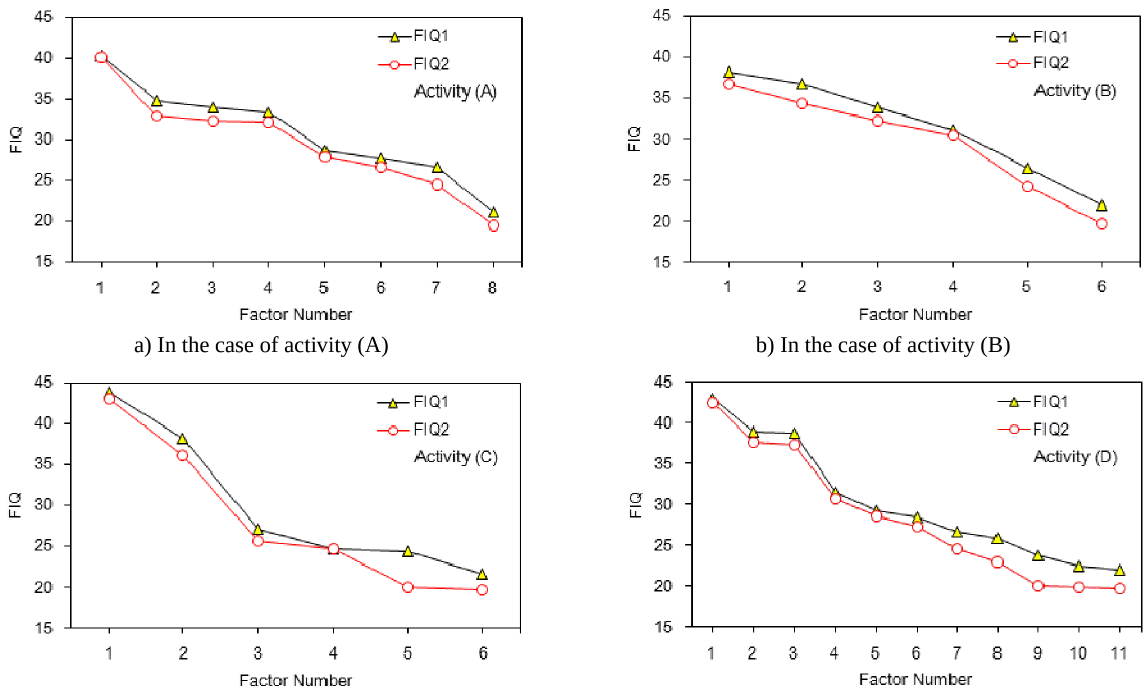
Fig. 1b The proposed membership function (MF2)

The output of the model is represented by Fuzzy Index for Quality (FIQ) which introduces the importance or magnitude of the factor. There are many relationships with varying values of PI, IIQ, and FIQ. These relationships can be represented using fuzzy associative memories (FAMs) and method suggested in previous works [15-17]. In this research, the relationships in the FAMs are suggested to satisfy the proposed membership function (FM2) as presented in Table 4. The logical rules are increased from twenty five rules using MF1 to forty nine rules using MF2. Mathematically the double premise rule can be transformed to the following rules: If (PI) and (IIQ) then (FIQ). Samples of rules extracted from the FAMs matrix are as follows: 1) If the PI is Low and the IIQ is Very Low then the FIQ is Very Low, 2) If the PI is The Highest and the IIQ is High then the FIQ is Very High.

Table 4 The proposed FAMs used to calculate the output using the new membership function (MF2)

[redacted]

The FAMQ model is applied on the collected data using the two membership functions: MF1 and MF2. The outputs of the model are the (FIQ) for each risk factor due to the inputs PI and IQ. Figure 2 shows comparisons for the values of the model outputs (FIQ1) and (FIQ2) due to using MF1 and MF2, respectively for the four activities of DPRCP. The factors are arranged in descending order due to the values of FIQ. It is observed from all of these figures that outputs due to the two membership functions take the same trend and the same behavior while the difference between them at any point does not exceed 5%. These results can verify that MF2 is suitable to be used in the assessment of risk factors affecting quality of an activity. The benefits for Using MF2 compared to MF1 that MF2 increases the choices for the respondents from 5 to 7 levels which may give more accuracy. In addition, using a large number of logical rules in the model (49 instead of 25) helps to increase the accuracy of the model.



a) In the case of activity (A)

b) In the case of activity (B)

c) In the case of activity (C)

d) In the case of activity D

Fig. 2 FIQ values based on MF1 and MF2 for the executed activities

5. Assessment for Risk Factors Affecting DPRCP Activities Quality

Preparing and casting piles (A) is considered the preliminary activity in the execution of DPRCP. In this activity, the selection of materials, casting place, and casting mold should be firstly prepared, and then piles are casted in molds prior to apply curing regime. As presented in Table 3 there were eight risk factors controlled this activity. By applying the FAMQ model to all factors that affect this activity using MF2 the values for FIQ2 can be determined. Table 5 shows the inputs of the FAMQ model in case of activity (A). The factors affecting this activity are ranked in descending order due to the values of FIQ2. For better illustration the relationship between FIQ2 and risk factors are drawn and presented in Figure 3.

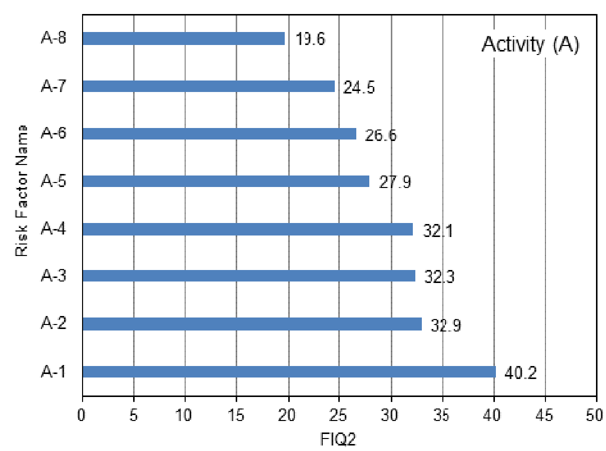


Fig. 3 Risk factors magnitudes due to FIQ2 for activity (A)

It is clear from this Figure that the risk factor (A-1) named (Poor materials quality) has a significant effect on the quality of this activity because it has the highest value of FIQ2 in this activity. Also, it is observed from this figure that the risk factors (A-2), (A-3) and (A-4) have closest values of FIQ2. In fact these risk factors are related to the used technique in the preparation of precast concrete piles and then FIQ2 values are almost the same. The lowest value of FIQ2 was obtained in the case of risk factor (A-8) that related to inappropriate casting method. This result is most likely related to the availability of modern techniques used in casting and then engineers did not face more challenges for the execution of this task.

Table 5 Inputs for factors affecting activity (A)

Name	Risk Factor Description	PI	IIQ
A-1	Poor materials quality, for example the gravel gradation	42.58	40.32
A-2	Using inappropriate tools (such as the type of casting mold)	33.55	42.10
A-3	Incorrect preparation and poor choice for casting and curing area	53.23	28.23
A-4	Weak connection between the pile reinforcement with the pile edge	32.58	34.19
A-5	Poor curing for the precast piles	37.26	27.42
A-6	No use for separation materials between piles during casting	31.29	25.16
A-7	Piles arrangement and number of piles in the casting and curing area	26.77	23.39
A-8	Inappropriate casting method	16.45	35.16

Positioning piles and steering the pilling machine (B) is the second activity needed for the execution of DPRCP. This activity is dealing with the determination of the required position for the driven piles based on design criteria of bridge project. This activity can be done by directing the driving machine to the required pile position. The site Engineer gives instructions for the driving machine crew to move for the required pile position using surveying devices. As presented in Table 3, there were six risk factors controlling this activity. The inputs for the FAMQ model for this factor are presented in Table 6 ranked in descending order due to the values of FIQ2. It is evident from this table that the selected risk factors have a significant effect on this activity.

Table 6 Inputs for factors affecting activity (B)

Name	Risk Factor Description	PI	IIQ
B-1	Poor system of fixing pilling machine	47.18	37.74
B-2	Using inappropriate surveying devices to steer the pilling machine	21.13	55.16
B-3	Difficulties of implementing marks to locate the pile over the water	42.74	32.74
B-4	Lack of specialized laborers running machine	30.65	37.42
B-5	Characteristics of the waterway section	22.90	28.23
B-6	Extreme weather conditions	18.39	16.77

The highest value for FIQ2 in this activity was obtained with the risk factor (B-1) as presented in Figure 4. This result is probably related to using driving machine with low technology and facilities for the purpose of controlling the movement of machine created many difficulties. It can also be seen that, the probability of occurrence of this activity is relatively high and that is confirmed herein due to many difficulties that occur during the execution. Also, factors (B-2), (B-3) and (B-4) have a significant effect due to the values of FIQ2. While the effect of risk factors (B-5) and (B-6) referred to the characteristics of the waterway section and weathering conditions have a lower effect on the value of FIQ2. This may be related to the use of high technology machines which help the crew to overcome such difficulties. Besides, these risk factors are considered nature phenomena that change from one site to another as well as from one season to another. Consequently, the effect of such risk factors on the value of FIQ2 can be classified as a moderate to low effect compared to the other investigated risk factors.

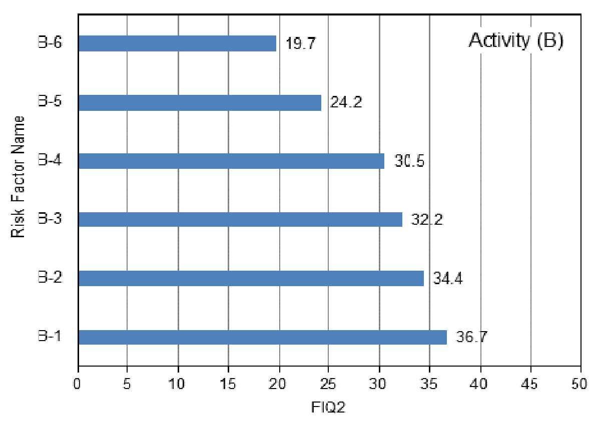


Fig. 4 Risk factors magnitudes due to FIQ2 for activity (B)

Handling piles (C) is one of the most important activities for the execution of DPRCP. Although this activity has a limited number of risk factors (6 risk factors), but it is considered a very difficult activity in the execution pile process due to transferring piles to the required positions in a safe manner. Table 7 shows the inputs for the FAMQ model while Figure 5 shows the FIQ2 values for the risk factors affecting this activity.

It is clear from these results that the risk factor (C-1) named (lack of specialized equipment's) is the most significant risk factor. In this case FIQ2 is the highest value in all risk factors affecting all activities and is considered the most important risk factor in the executing of DPRCP. There is no much difference observed between the effects of risk factors ranging from (C-3) to (C-6) due to their FIQ2 values compared to the risk factor (C-1). Based on the value of FIQ2 for the risk factor (C-1), it is important to highlight on the efficiency of the driving machine because it plays an important role in the execution of DPRCP. Also, this Figure indicates that the risk factors (C-3) and (C-4) have approximately the same influence as proved by the value of FIQ2. Actually, the risk associated with the activity of handling pile is not only limited to the damage of pile, but also the risk on the safety of the driving machine crew.

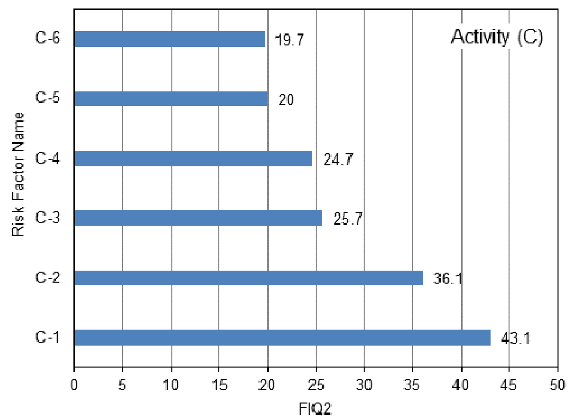


Fig. 5 Risk factors magnitudes due to FIQ2 for activity (C)

Table 7 Inputs for factors affecting activity (C)

Name	Risk Factor Description	PI	IIQ
C-1	Lack of specialized equipment's	44.52	51.77
C-2	Handling the pile in an unsafe manner or from non-specific lifting places	40.48	36.94
C-3	Distance of transferring the pile from casting and curing area to the specified pile location	30.97	24.03
C-4	Inability of the pile to bear the stresses resulting from the handling process	19.52	43.87
C-5	Characteristics of the waterway section such as channel width and water velocity	19.84	31.61
C-6	Extreme weather conditions	16.77	21.94

Driving piles (D) is one of the burning issues for the execution of DPRCP since it is considered the final and serious stage. This activity is made by driving the pile to the required depth according to design criteria for the project and this task can done by using special driving machine. In fact there are many numbers of risk factors controlling this activity compared to the other investigated activities. The number of risk factors for this activity is reached to eleven. The inputs of the FAMQ model for this activity are presented in Table 8 and FIQ2 is presented in Figure 6.

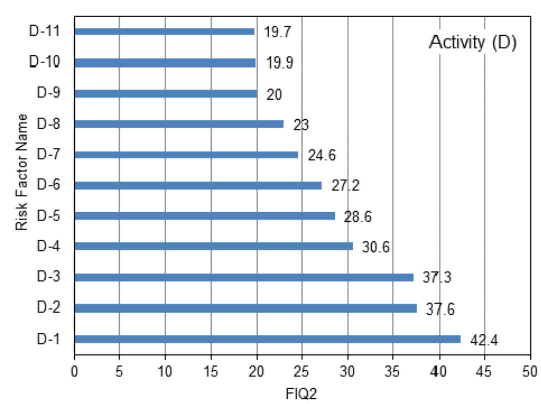


Fig. 6 Risk factors magnitudes due to FIQ2 for activity (D)

It can be noted that the factor (D-1) which describing the difference between soil boring report and the nature of soil has the highest value for FIQ2 in this activity. In fact this risk factor plays an important role, not only in this study because its effect extends to all foundation structures. This is related to the fact that the identification of soil properties presented in soil report only represents the location of boring and not the whole site. Geotechnical engineers assume the profile of soil obtained by boring represent the whole site since it is difficult to implement more number of borings. It is obvious from this figure that the risk factors (D-2) and (D-3) have a significant effect on this activity due to the value of FIQ2. This result is probably related to the adjustment verticality of piles during driving process where it has many challenges. These challenges are not limited to the quality of driving machine, while the response of machine crew to take the action toward the correction of pile inclination is not an easy task. This is probably related to any mistake occurred due to the adjustment of the verticality of piles as pushing the pile will cause overstress for piles that may lead to damage of pile. There is no much difference between the influences of risk factors ranging from (D-4) to (D-6) values of FIQ2. This result is probably related to the investigated risk factors controlled by the performance of machine crew and site engineers. This means that these factors are controlled by human more than the tools used for driving process.

Table 8 Inputs for factors affecting activity (D)

Name	Risk Factor Description	PI	IIQ
D-1	Differences between soil boring report and the soil nature which lead to needing pile extension or stop driving	43.39	51.13
D-2	The machine or the pile is not vertically	38.23	40.81
D-3	Lack in using new techniques in driving or in case of obstacles that constrain the driving process	38.39	48.87
D-4	Lack of specialized laborers running machine	30.81	41.29
D-5	Lack of follow-up and slow decision during the process of driving	28.23	45.16
D-6	Non suitability of the hammer distance and driving rate for the pile	26.61	33.87
D-7	Collapsing of the pile head due to non-using a cushion to absorb the driving energy	23.23	31.77
D-8	Problems due to site conditions such as railways adjacent the site	34.52	22.10
D-9	Poor arrangement for piles precedence execution	19.19	20.32
D-10	Environmental problems due to driving such as noise or steam	38.06	16.94
D-11	Stopping during driving a certain pile	17.10	21.29

6. Box Plot Analysis for Factors Affecting DPRCP Activities

The boxplot invented by John Tukey [18], is an efficient way for presenting data. It can provide a quick visual summary that easily shows center, spread, range and any outliers. The box contains 50% of the data, and the upper edge of the box represents the 75th percentile, while the lower edge represents the 25th percentile, and the median is represented by a line drawn in the middle of the box. The ends of the lines (called whiskers) represent the minimum and maximum values of the data set, unless there are outliers. In this research, the boxplot analysis is introduced to summarize and compare the sets of data for the FIQ2 values for risk factors that affect DPRCP activities. The boxplot is drawn for each activity and constructed side-by-side for the four activities and presented in Figure 7. It can be noted that the longest range is for activity (C) which is named handling piles. This wide range for FIQ2 values refers to the high differences among the FIQ2 values for factors affecting this group. This activity includes the highest FIQ2 value for factor (C-1) which is considered the highest value for all risk factors affect the four activities. This confirms the importance of this risk factor on handling, and transferring piles safely. Although the activity (D) which is dealt with the driving piles faces the largest number of risk factors, it does not have the largest range for the boxplot. This reflects that the FIQ2 values in this activity are close in addition to the high values for the most of risk factors. This proves that the investigated risk factors for this activity are significant compared to other investigated activities. This result matches with technical recommendation reported in literature about the importance of the stage of driving pile compared to other activities. This also refers to difficulty of rework of this activity. Generally, in all the investigated sets, there is no risk factor located outlier. This proves that the selection of the risk factors for all the investigated activities is significant.

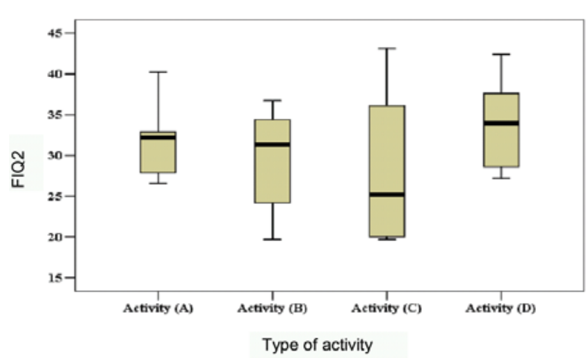


Fig. 7 The Boxplot for factors affecting DPRCP activities

7. Conclusions

This study aimed to light the way for the partners in the industry of DPRCP, to help them through identifying the activities and risk factors affecting each activity. In addition to assessing these factors due to their effect on the activities quality because each activity is affected by a combination of many risk factors. For that, a semi-structured interviewing methodology is introduced to identify the activities and the associated risk factors affecting each activity. A new membership function is used to satisfy the quality of the activities and new fuzzy associative memory is used to represent the relations between PI and IIQ. The FAMQ is used to calculate the FIQ and to verify the proposed membership function. Results showed that the proposed membership function can be used in defining the quality of activities. Based on model results and analysis, the following conclusions can be drawn as presented below:

1. The most important risk factor affecting the quality of activity (A), preparing and casting piles, is the poor materials quality. While the most important risk factors which affect the second activity (B), positioning piles and steering pilling machine, are poor system using in fixing the pilling machine, using inappropriate surveying devices, and difficulty of making marks for pile positioning.
2. Most of the risk factors that controlled the activities C (handling) and D (driving) are found the lack of the specialized equipment's and the difference between soil boring report and site nature respectively.
3. The most important activity is (D), driven piles, because it is affected by a large number of risk factors with high FIQ2 values.
4. It is recommended that engineers deal with DPRCP should consider the major risk factors presented in this study, which controlled the activities of DPRCP in their quality management plan for such projects in Egypt.
5. The recommendations and results obtained from this study are not limited to apply in Egypt while they can be extended worldwide to achieve high performance and quality for DPRCP industry.

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