IMPACT FACTORS ON TIME AND COST IN PILE CONSTRUCTION

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Construction activities have increased due to Saudi Arabia's Vision 2030 programs, accelerating change across all sectors. However, the pile construction sector has already experienced significant time and expense overruns that have had a negative impact on all parties. This study aims to identify and investigate the significant risk influencing the timing and cost of pile construction projects in Saudi Arabia. The most risks were gathered and found in the literature. Two questionnaire-based surveys were undertaken to establish the perspectives of the construction experts on the degree of probability of occurrence of each risk. To collect the qualitative and quantitative experts’ responses, the data questionnaire was analyzed using the Artificial Neural Network (ANN) model to identify the significant risks in terms of cost and time of pile construction. The main finding showed that the significant risks are DR1 (improper and insufficient assessment of soil), CR1 (labor mistakes, rework, and idle times), OGR5 (Delay or inability of the owner to provide full possession of site), ECR1 (lack of funds: the lack of cash flow by the contractor), ECR6 (foreign exchange risks: unstable exchange rates, transfer restrictions, and supply and demand balance), ECR5 (economic crisis), PGR1 (failure to obtain approvals or permits), CR3 (low credibility), SCR1 (lack of management skills). This study assists the decision makers in a deeper understanding of the influencing factors, allowing them to make effective scheduling and comprehensive control over pile foundation projects.

Keywords: Risk, Score, Neural network, Management.

1 INTRODUCTION

The deep foundations represent significant member structures of large projects such as high-rise buildings, bridges, and wind turbines. Moreover, due to the existence of numerous different resources (equipment, labor, materials, and supplies) that are proportionate to fulfilling its objectives, deep foundation construction is one of the most complex construction operations to implement. Because no scientific estimating methodologies are used in the industry, managers will plan the piles' construction projects arbitrarily, leading to erroneous results that could cause delays, lack of finance, and other dangers. These issues may influence the primary purpose of a construction project, which is to meet the owner's functional requirements based on the nature of the project while achieving schedule, budget, and quality objectives (Aziz 2004). Failure to achieve such objectives can be frequently attributed to the failure of contractors to deal with unanticipated risks (Hosny et al. 2018). Therefore, effective risk management aims to creatively identify, evaluate, and control risks in order to convert as many unknown hazards into known risks. The analysis performed by Hosny et al. (2018) was only a qualitative analysis to rank the risk, and they did not connect with quantitative analysis. Moreover, it was clear that there are no research studies on the pile construction industry risks in KSA's working conditions, which will be the main
objective of this paper, the questionnaire and qualitative were designed in a questionnaire with 53 questions about risks and two questions related to the pile installation's time and cost, respectively.

In KSA, the pile construction sector has already experienced significant time and expense overruns that have had a negative impact on all parties. In addition, the piles need to be studied to understand the impact of their cost and time in the KSA construction industry. The paper addressed this issue by collecting the numerous risks described in the literature and conducting a questionnaire survey with 12 construction pile industry experts in KSA, followed by a phone call to review and confirm the information. After that, the questionnaire data were statistically analyzed and then utilized by the Artificial Neural Network (ANN) to rank the most significant risks countered in KSA's construction pile. Identifying the significant risks of pile construction issues (cost and time) is essential to mitigate the time and cost overrun and assist the stakeholders in considering the preventative/corrective procedures.

2 METHOD

The authors adopted a cross-sectional questionnaire-based survey to evaluate risk factors related to pile construction projects in KSA. The paper's methodology consists mainly of three sequence parts as; collection data, design and implementation questionnaire survey with phone calls to the 12 experts, and assessment and ranking cost and time of pile construction risks.

2.1 Collecting Data

The risks that may influence the time and cost of pile construction were collected from the literature, and the collected factors were classified as; external risks, design risks, management risks, construction risks, subcontractor risks, equipment risks, political and governmental risks, economic risks, owner generated risks and site risks, which were collected by (Eldosouky et al., 2014; Griffis & Christodoulou, 2000; Hosny et al., 2016; Mulcahy, 2019).

2.2 Design and Implement the Questionnaire Survey with Experts

After gathering risks data, the questionnaire survey to experts was designed based on the gathering risk data from the literature. The questionnaire was carried out in two sequence phases. The first questionnaire was to check whether the risk has an influence or non-influence on the cost and time of pile construction. Moreover, the questionnaire allows additional risks that may be happened in the pile construction industry of KSA will be collected by the experts. After inserting the additional risks into the appropriate group, the second questionnaire survey, which consisted of 53 questions representing the qualitative questions, was performed to determine the degree of probability occurrence (P) and degree of impact (I) on the two issues (time and cost of pile installation) per question using five scale Likert scale. The scale from 1 to 5 represented very low, low, moderate, high, and very high, respectively. It should be noted that the questionnaire in the two stages was designed in Arabic language to improve the participants’ ease of accessibility and understandability. Two quantitative questions related to the time and cost per single pile construction were added to connect the quantitative and qualitative analyses. Hence, each respondent had 53 qualitative responses and two quantitative responses.

2.3 Assessment and Ranking of Risks Using the ANN Model

The method to extract the knowledge from Likert scale survey data consists of two steps. The first step is to train and prune the neural network using a multi-layered algorithm. The second step is to apply an ANN algorithm to extract rules from the trained network. Responses to a Likert-scale
survey are usually in a non-numeric form. The ranking procedure is shown in Figure 1. For neural network training, responses were converted from 0.0 to 1.0. For per respondent and risks (response of question), the P and I were normalized by the maximum value Likert scale (5). Then, the risk score (RS) was computed by multiplying P with I, as shown in Eq. (1);

$$RS = P \times I$$ (1)

After that, the total risk score of the group (TRS) was determined by summation of the RS of its risks, as shown in Eq. (2);

$$TRS_i = \sum RS_i$$ (2)

where \(n_g\) is the number of risks in the group. Therefore, ten of TRS were obtained per respondent. After that, the TRSs values of the ten respondents were standardized using Eq. (3):

$$Standardize(TRS_i) = \frac{(TRS_i - TRS_{min})}{(TRS_{max} - TRS_{min})}$$ (3)

where \(TRS_i\) is the total score of the \(i^{th}\) group risk, \(TRS_{max}\), and \(TRS_{min}\) are the maximum and minimum of the total risk score, respectively, and \(n\) is the number of groups. The standardized data were used as input data in the ANN that will be detailed in the following section. The ANN is one technique of machine learning (ML). It is usually used to analyze and forecast data. Its structure consists of input, hidden, and output layers, with the number of neurons for each layer depending on the application's purpose.

The ANN, in this paper, was utilized to evaluate and determine the most significant risks. The IBM SPSS software was adopted due to its efficiency, simplicity, and capacity to visualize data using diagrams (Badawy et al. 2022). The input layer compromises the ten neurons as; external risk (ER), design risk (DR), construction risk (CR), management risk (MR), sub-contractor risk (SCR), equipment risk (ER), political and governmental risk (PGR), economic risk (ECR), owner generated risk (OGR), and site risk (SR). The values inserted in the neurons were the standardized TRS of the ten groups. On the other hand, the output layer had two neurons as cost and time. The hidden layer was set as one layer with many neurons of \((2m+1)\), where \(m\) is the number of input layers (Zayed 2001). The structure of ANN is shown in the appendix (Figure A1). In general, the ANN structures consider linking the qualitative data inserted in the input layer and the quantitative data considered in the output layer. Therefore, the quantitative and qualitative analyses were connected and considered in the paper results.

3 FINDINGS AND DISCUSSION

The questionnaire survey and phone calls were performed to the 12 pile construction experts with ten years of experience in the pile construction industry in three sequence stages. The experts consist of two academics, an engineer manager, and nine engineers who supervised the implementation of pile foundations. The experts' response, the first stage was represented to determine the risks that may have occurrence and impact on pile construction in KSA, recommended adding some risk such as "the distance between the pile and the adjacent pile, DR7", "the nature of the project (piles for the foundations of a building and a bridge, or piles supporting the excavation walls), DR8", "the number of equipment on site, EQR8", and "drilling machine size, EQR9". These risks were added to the appropriate group, as shown in Table A1 (in the Appendix). Then, the questionnaire was implemented as second stage. The second stage aims to determine the probability occurrence (P) and impact risk (I) for every 51 risks (qualitative data), as well as provide the average cost and duration of pile construction (quantitative data). Table A3 (in the Appendix)
shows the results of the second stage after computing the risk score per risk. On the other hand, expert answers for the cost and time pile installation provide data with significant variance in unit and magnitude.

For obtaining the appropriate cost and time pile construction value, the following limitation was considered in the paper: the diameter pile is one meter and the pile depth is twenty. Then, the third stage was performed by performing phone calls to each expert and explaining. The experts were asked the following questions: “What is a type of ground condition (rock, clay, sand)?”; “How much is the drilling rate in an hour?”; and “How much is the total cost of constructing the pile per meter?”. Based on the answer to the previous question, the cost and time of single construction pile were determined, as shown in Table A3 (in the Appendix). Therefore, the three ground conditions were assigned as input data beside 53 risks. The ranking risks based on the
quantitative and qualitative analysis (Figure 2(a)) were compared with the ranking of the qualitative analysis (Figure 2(b)). The most significant risk in the cost and time pile construction are presented in Table A4 (in the Appendix). It should be noted that the first method ranking depends on the ANN models, while the second method ranking is based on the average RS values of the risk. There are significantly different between the two methods' ranking. Generally, the two methods consider the construction risks (CR), design risks (DR), and economic risks (ECR) as significant impact risks. Unlike the first method (quantitative and qualitative analysis), the qualitative analysis ranking considers the management risks (MR) and site risks (SR) as significant risks. In addition, the study's results by Hosny et al. (2018) were utilized for the risk ranking comparison. The study top ten risks of the study are shown in Figure 3(c). The results indicated that the "improper and insufficient assessment of soil, DR1" had the highest risk on the cost and time construction pile, which was in agreement with the results of this paper. Their results also indicate that ECR1 (lack of funds: the lack of cash flow by the contractor), and ECR6 (foreign exchange risks: unstable exchange rates, transfer restrictions, and supply and demand balance) hazards are among the top ten hazards in the piling industry, which is consistent with the results reached in this study, as shown in Figures 3(a) and 3(c). However, the rest of the ten factors are quite different, this is due to the difference in the method used, as the method used in Hosny's research is the descriptive analysis, while the method used in the research is a mixture of descriptive and quantitative analysis. The difference may also be attributable to the different market conditions and environments between KSA and Egypt.
4 CONCLUSIONS

The paper dealt with identifying the most risks that may be countered in the pile construction industry in KSA using qualitative and quantitative analysis. The analysis consists of three main stages. The first stage collected the most pile construction risks in the literature. The second stage was represented carrying out the questionnaire survey and phone call with the 12 pile construction experts in KSA. The third stage was to analyze questionnaire data by conducting ANN models to identify the ten significant risks. The results revealed that the significant risks for cost and time pile construction are DR1 (improper and insufficient assessment of soil), CR1 (labor mistakes, rework, and idle times), OGR5 (delay or inability of the owner to provide full possession of site), ECR1 (lack of funds: the lack of cash flow by the contractor), ECR6 (foreign exchange risks: unstable exchange rates, transfer restrictions, and supply and demand balance), ECR5 (economic crisis), PGR1 (failure to obtain approvals or permits), CR3 (low credibility), SCR1 (lack of management skills). This study aids the decision-makers in developing a more profound knowledge of the influencing aspects, enabling them to plan pile foundation projects effectively and exercise complete control over them.

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Data Availability Statement

The raw data supporting the findings of this paper and appendices are available on request from the corresponding author.

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