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## FULL LENGTH ARTICLE

# Factors influencing sub-contractors selection in construction projects

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**Abstract** Selection of the best sub-contractor is a vital process in construction projects. There are many factors that must be taken into consideration when selecting sub-contractors. Improper selection of sub-contractors might lead to many problems during work progress. These include bad quality of work, and delay in project duration. This process is controlled by many factors. Forty six factors are collected from previous studies that influence sub-contractor selection. This paper identifies the most important factors that influence the selection of sub-contractors. A questionnaire was distributed to experts in the construction domain to determine the importance of factors that are taken into consideration by the main contractor to select the most suitable sub-contractor. A survey was carried out which was conducted with 29 experts in the construction field to determine the score of each factor. Statistical analysis is carried out on the feedback of the respondents of the survey. By using SPSS software, the frequency of the results of the questionnaire was determined. Examples of crosstabs between some of the most important factors are presented to provide a comparison between two factors. The mean score of each factor was determined and the p-value was calculated using the SPSS software, the significance of each factor used in the questionnaire is determined. Any factor that has a p-value less than 0.05 is considered a significant one.

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## Introduction

The main objectives of the contractor selection process are to reduce project risk, maximize the quality and maintain strong relationships between project parties. The same concept is applied to the sub-contractor selection process. Some owners regard the cost as the most important criteria to base the contractor selection process on; however, research recommends that a multi-criteria selection process should be further taken into consideration. Many main contractors and owners

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are merely interested in the lowest bidders. But there are other criteria that should be taken into consideration. In a study that was performed by Turksis [1], 13 criteria for selecting the best contractor are introduced such as: “history of reasonable bid price submissions”; “a work history that indicates specialization and quality of workmanship in a particular construction skill”; “contractor’s degree of quality control”; “decorum, conduct and non-disruptiveness of contractor staff and subcontractors”; “coordination of operations that will cause noise, vibrations, dust, odors, safety concerns and other activities”; “responsiveness to warranty issues”; “Flexibility and cooperation when resolving delays”; and “ability to meet project schedule”. Abiding by such criteria, or on others depending on the situation, leads to the right selection of the best alternative, which has many benefits for all parties in the construction project; such as high quality finishing, meeting deadlines based on the estimated time, as well as abiding by the estimated cost.

Consequently, there are many methods that can be used in the decision making process of selecting a contractor. These methods include: “multi-criteria decision making (MCDM), bespoke approaches (BA), multi-attribute analysis (MAA), multi-attribute utility theory (MAUT), and decision support systems for contractor pre-qualification – an artificial neural network approach” (Darvish et al. [2]). In a study by Darvish et al. [2], multi-criteria decision making (MCDM) method is used, taking into consideration the following criteria of selection: technology and equipment, management, experience and knowledge of the technical staff, financial stability, quality, being familiar with the area or being domestic, Reputation, and creativity and innovation. Despite setting several contractor selection criteria, the final decision should consider both; the criteria set and the competitiveness of the price. In that sense, different countries vary in the approach they follow in order to take the final decision. Countries such as Denmark, Italy, Portugal, South Korea, France, Australia, Saudi-Arabia, Turkey, Canada, the United States of America, Lithuania and Iran, have different approaches as shown in Table 1.

A study by Walraven and De Vries [3] applied the process of selecting the best contractor. The research method of this study is divided into four parts. The first part determines 34 sub-criteria of contractor selection driven from other studies. Some of these factors resemble those required for choosing

the subcontractor, such as; “prevention of vandalism” and “energy saving materials and installation.” These factors were grouped into eleven criteria. The second part is mainly a questionnaire which was conducted with field experts. The third part represents the calculation of the relative weights of the 34 sub-criteria. The fourth part states that “the value of a bid will be divided by the price resulting in the value-price ratio; the higher the ratio the more value for money for the client.” The minimum value/requirements is the related set of minimum necessities, maximum price the client is ready to reimburse, minimum value-price ratio showing the difference between the value and the price. Hartmann et al. [4] set four essential criteria for choosing a subcontractor; “price, technical know-how, quality and cooperation.” In order to determine the relative importance of each criterion, the mean, median and standard deviation were calculated. The four criteria are considered essential ones. Usually, maximizing profits and minimizing costs come as crucial objectives of a contractor. Consequently, setting price as one of the criteria of choosing a subcontractor is essential; in the real world a subcontractor who offers the lowest price is likely to be selected. However, as previously highlighted, price cannot be the sole criteria based on which selection occurs. Another important criterion is the “technical know-how” [4]. It was suggested that a subcontractor has to prove professionalism, experience and knowledge of specific technical issues; as a subcontractor is mainly “hired to perform specific tasks of a project” which require technical knowledge [4].

As explained, a subcontractor who maximizes profits, through high quality work backed with strong technical know-how and a cooperative attitude is considered among the best options. In that sense, a study by Doloi [5] supported this conclusion through introducing 43 sub-criteria to determine the best alternative. The study concluded that the low tender price alone is not an indicator of the alternative/contractor’s trustiness. The research has three objectives; first, to determine the essential criteria related to the selection of a contractor; second, to examine and evaluate the extent to which these criteria are essential to a successful “project delivery”; and third, to set up “the predictive models” on the contractor selection criteria “influencing target performance and overall success in projects” [5]. In order to get a comprehensive idea

**Table 1** Approaches for contractor’s selection [2].

| Country                      | Decision making approach                                                                                                                                          |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Denmark                      | Rejecting the highest two and the lowest two and selecting the contractor that offers a price closest to the average                                              |
| Italy, Portugal, South-Korea | Rejecting the highest one and the lowest one and selecting the contractor that offers a price closest to the average                                              |
| France                       | Rejecting the contractor that offers an abnormally low price                                                                                                      |
| Australia                    | The process is implemented in two stages: first, evaluating the contractor’s experience; second, bargaining for a price then occurs                               |
| Saudi-Arabia                 | The lowest bidder is selected provided that the bid is not less than 70 percent of the owner’s cost estimate                                                      |
| Turkey                       | The lowest price determines the selection                                                                                                                         |
| Canada, USA                  | The lowest bidder is selected                                                                                                                                     |
| Lithuania                    | The lowest bidder is selected                                                                                                                                     |
| Iran                         | The lowest bidder is selected. The process occurs in two stages: first, the contractor’s pre-qualification is evaluated; second, the lowest price mechanism works |

about the effect of the different criteria on the contractor selection process, a survey was conducted, which is considered an important tool to identify the significance of each criterion. A questionnaire is also considered the best method to use in cases of non-accessibility to “documented data”. This paper presents a study on the factors that influence the selection of sub-contractors in construction projects. Forty six factors are collected from previous studies that influence sub-contractor selection. This paper identifies the most important factors that influence the selection of sub-contractors. A survey was carried out which was conducted with 29 experts in the construction field to determine the score of each factor. The size of the sample required from the targeted population is the total number of contractors registered by the Egyptian Federation for Construction and Building Contractors (EFCBC). The minimum size of the sample required from the targeted population was determined statistically according to Kish [6] as per Eqs. (1) and (2).

$$n_0 = \frac{p * q}{V^2} \quad (1)$$

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \quad (2)$$

where:  $n_0$ , is first estimate of sample size;  $p$ , the proportion of the characteristic being measured in the target population;  $q$ , complement of  $p$  or  $1-p$ ;  $V$ , the maximum standard error allowed;  $N$ , the population size; and  $n$ , the sample size.

The total number of contractor companies ( $N$ ), registered in Egyptian Federation for Construction and Building Contractors (EFCBC), in the year 2007 is 58,991, and the first class contractor's companies are 1716. Hence,  $p$  is estimated to be the ratio between the first class of contractor's companies to the total number of contractor companies which is 0.029. To account for possible error in the qualitative answers from the questionnaire, the maximum standard error  $V$  was set at 10%. Substituting in Eqs. (1) and (2), the minimum sample required was calculated to be 2.816. This means that the minimum sample size is approximately 3.0.

### Factors identification and statistics

Forty six factors that are clustered in ten criteria are considered in the survey to determine the most important factors in selecting sub-contractors. These criteria and their factors are listed in Table 2. These factors were gathered from the literature [7–10]. This section presents the statistics and mathematical calculations which were carried out using SPSS software to provide the crosstabs and the frequencies. Then, at the end of this section, there is a table for determining the significant factors. Three types of statistical analyses are performed on the data: frequency calculations, cross-tabulation calculations, and identification of significant factors.

#### Frequency calculations

By using the SPSS software, the frequency of the results of the questionnaire was determined. This section consists of tables of some of the most important factors and determines the number of the responses for each score, ranging from 1 being the least important to 5 being the most important. The

frequencies of importance level and the mean score for the different factors are listed in Table 3.

#### Identification of significant factors

Using the mean score of each factor and calculating the p-value by using the SPSS software, the significance of each factor used in the questionnaire is determined. Any factor that has a p-value less than 0.05 is considered a significant one. As per Table 4, the significant factors are determined based on the p-value and the mean score. Any factor that has a p-value less than 0.05 has a mean score of more than 3.00. There are thirteen factors with a p-value more than 0.05, so they are not significant factors. Although some of the non-significant factors have a mean score more than 3.00 this is not an indicator that these factors can be significant. The p-value result is a crucial indicator to the significance of factors. In this table, determining the significant factors occurs through identifying their mean scores and p-value. The mean score which acts as an identifier of the most important versus the least important factor is 3.00. This mean score can be identified as an average mean score; since a mean score less than 3.00 has no significance and more than 3.00 is significant. Therefore, each significant factor is considered of high importance when its mean score is more than 3.00, and has a p-value less than 0.05.

#### Cross-tabulation calculations

Crosstab is the comparison between two factors which is done by using the SPSS software. The crosstabulation is defined as “Across-tabulation” and is a two (or more) dimensional table that records the number (frequency) of respondents that have the specific characteristics described in the cells of the table. Cross-tabulation tables provide a wealth of information about the relationship between the variables” [11]. This section presents examples of crosstabs between some of the most important factors only. These factors are: tender price, contractor's difficulty in reimbursement, Failure to complete contract, quality, experience of technical personnel, Suppliers incompetency to deliver materials on time, disputes, and arbitration, Failure to comply with the quality specifications, flexibility, and cooperation when resolving delays, delay, flexibility in critical activities, Reputation, knowledge of construction regulations and physical resources. Table 3 compares between two of the most important factors which are quality and failure to comply with the quality specifications. When the Quality factor has moderate importance, two of the responses said that the Failure to comply with the quality specifications factor has the highest importance. Also when the Quality factor has weak importance, one response gave the failure to comply with the quality specifications factor moderate importance. The total number of responses of both factors is 29, which is the total responses number of the questionnaire survey. Table 5 clearly sets a comparison between two factors.

The Quality factor has 13 responses with the highest importance while the Failure to comply with the quality specifications factor has different importance rates. On the opposite side there are 18 responses that gave the Failure to comply with the quality specifications factor the highest importance while the Quality factor has different importance rates. This shows that the Failure to comply with the quality

**Table 2** Factors influence sub-contractors selection.

| Criterion                                                      | Factor                                                                                                                     | Definition                                                                                                                                                               |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cost                                                           | Cost overruns                                                                                                              | The cost of the project exceeds the expected value of the project during the construction stage                                                                          |
|                                                                | Flexibility in payment terms and conditions                                                                                | If there is any flexibility from the subcontractor to decrease the cost of one item or more                                                                              |
|                                                                | Tender price                                                                                                               | It is the price offered by the subcontractor to win the tender (the lowest price wins)                                                                                   |
|                                                                | Sub-contractor's difficulty in reimbursement                                                                               | If the subcontractor finds any difficulty in reimbursement to the materials supplier or in paying the salary of his staff each month                                     |
|                                                                | Failure to complete contract                                                                                               | How many projects the subcontractor failed to complete                                                                                                                   |
|                                                                | Financial stability                                                                                                        | Whether the subcontractor faces any financial problems that lead to financial instability                                                                                |
|                                                                | Financial references                                                                                                       | What is the source of the funds of the subcontractor who applied for the tender?                                                                                         |
| Quality                                                        | Quality                                                                                                                    | What's the standard of quality of the subcontractor (the standard of quality is determined based on the past projects that the subcontractor worked on)?                 |
|                                                                | Sub-contractor's poor management ability                                                                                   | If the laborers of the subcontractor produce bad quality work                                                                                                            |
|                                                                | QA/QC programs                                                                                                             | If the subcontractor has quality assurance and quality control engineers or not                                                                                          |
| Staff's behavior and experiences                               | Energy saving materials and installations                                                                                  | When the laborers of the subcontractor are keen on the process of energy saving while working with equipment                                                             |
|                                                                | Poor competency of laborers                                                                                                | If the laborers have poor competency especially in time management and work quality                                                                                      |
|                                                                | Experience of technical personnel                                                                                          | The years of experience the technical personnel gained in their field (technical person: professional laborers like the steel fixer, carpenter, painter)                 |
|                                                                | Decorum, conduct and non-disruptiveness of the staff                                                                       | The way the subcontractor's staff deal with others in the projects; whether they maintain appropriate decorum or not                                                     |
|                                                                | Prevention of vandalism                                                                                                    | If the laborers of the subcontractor commit any kind of vandalism in the work with other subcontractors and the main contractor                                          |
|                                                                | Cooperation with the other subcontractors on the project and in the vicinity                                               | The cooperative attitude with other subcontractors and vicinity                                                                                                          |
|                                                                | Creativity and innovation                                                                                                  | Whether the subcontractor's engineers have the creativity to solve complicated problems that may face the main contractor and the owner, and to find innovative solution |
| Safety                                                         | Labor force retention                                                                                                      | The memory of the subcontractors' laborers when given a specific task                                                                                                    |
|                                                                | Jobsite cleanliness during projects and upon leaving jobsites                                                              | The keenness of the laborers to leave the jobsite clean during and after their work time                                                                                 |
|                                                                | Prosecution due to unlawful disposal of construction waste, serious air and water pollution due to construction activities | During the construction stage, does the subcontractor cause any air or water pollution?                                                                                  |
|                                                                | Safety consciousness on the job site                                                                                       | Does the staff of the subcontractor maintain safety consciousness on the job site? (such as safety shoes, hard hat, and other safety precautions)                        |
| Insurance, repair and warranty for the employees and equipment | Onsite plant maintenance and repair programs                                                                               | Is the subcontractor keen on the maintenance and repairing for his equipment?                                                                                            |
|                                                                | Responsiveness to warranty issues                                                                                          | Is the subcontractor keen on having equipment with warranty on them?                                                                                                     |
|                                                                | Not buying insurance for major equipment and employees                                                                     | When the subcontractor does not provide insurance to his staff and equipment.                                                                                            |
| Disputes and risks                                             | Suppliers incompetency to deliver materials on time                                                                        | If the materials are not delivered on time, leading to a shift in one work activity or more                                                                              |
|                                                                | Disputes and arbitration                                                                                                   | Whether the subcontractor have a history of disputes and arbitration in any previous work                                                                                |
|                                                                | Failure to comply with the quality specifications                                                                          | Does the subcontractor fail to abide by the quality specifications of the projects?                                                                                      |
|                                                                | Lack of readily available utilities on site                                                                                | Does the subcontractor provide utilities such as bathrooms and offices to his engineers and laborers?                                                                    |

**Table 2** (continued)

| Criterion                  | Factor                                                                  | Definition                                                                                                                                       |
|----------------------------|-------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Risk avoidance             | Does the subcontractor predict possible risks to be able to avoid them? |                                                                                                                                                  |
| Time                       | Flexibility and cooperation when resolving delays                       | When there is a delay -in an item- facing the subcontractor and the main contractor, how can they both cooperate to resolve this delay?          |
|                            | Delay                                                                   | If the subcontractor is accustomed to time delays in the past projects                                                                           |
|                            | Length of time in industry                                              | How many years has the subcontractor been working in the industry?                                                                               |
|                            | Flexibility in critical activities                                      | How can the subcontractor deal with the critical activities during the construction stage?                                                       |
|                            | Flexibility in the noncritical activities                               | How can the subcontractor deal with the noncritical activities during the construction stage?                                                    |
| Experiences of the company | Reputation                                                              | Does the subcontractor have a good Reputation in his surrounding area? (high work quality, sufficient time management and reasonable cost rates) |
|                            | Being familiar with the area or being domestic                          | Is the subcontractor familiar with the area where the project's tender is located? (for instance owning a local company)                         |
|                            | Knowledge of construction regulations                                   | Is the subcontractor aware of important construction laws, such as FIDIC?                                                                        |
|                            | Volume of work committed                                                | The volume of work accomplished by the subcontractor in past projects                                                                            |
|                            | Experience in local area                                                | What is the experience of the subcontractor in the area of the tender?                                                                           |
| Tender                     | Scale of projects completed                                             | The scale of the projects that the subcontractor worked in                                                                                       |
|                            | Tender quality                                                          | The quality of the hardcopy of the tender given by the subcontractor                                                                             |
|                            | Willingness to tender                                                   | The weight the subcontractor puts on winning the tender; whether he cares enough or not                                                          |
| Others                     | Site proximity                                                          | What is the distance between the main office of the subcontractor's company and the site where he works?                                         |
|                            | Ongoing work commitments                                                | How many projects does the subcontractor work on in parallel with a current project?                                                             |
|                            | Physical resources                                                      | The subcontractor's physical resources, including the equipment and tools                                                                        |
|                            | Relationships with the client                                           | The relationship between the client and the subcontractors who applied in the tender                                                             |

specifications factor dominates the Quality factor. Table 6 shows the relationship between the Supplier's incompetency to deliver materials on time and Failure to comply with the quality specifications factors. As shown in the table there is no response when the Supplier's incompetency to deliver materials on time has the highest importance and the Failure to comply with the quality specifications has moderate importance. Also at different importance rates of the Supplier's incompetency to deliver materials on time, the Failure to comply with the quality specifications has the highest importance by a difference of 18 responses. On the opposite side, at different importance rates of the Failure to comply with the quality specifications, the Supplier's incompetency to deliver materials on time has a highest importance by a difference of seventeen responses. This means that the Failure to comply with the quality specifications factor is more significant than the Supplier's incompetency to deliver materials on time.

Table 7 shows the relationship between the Failure to comply with the quality specifications and the Flexibility and cooperation when resolving delays factors. As shown in the table, there is no response when the Failure to comply with the quality specifications has the highest importance and the Flexibility and cooperation when resolving delays has moderate importance. Also at different importance rates of Flexibility and cooperation when resolving delays factor, the Failure to comply with the quality specifications has highest importance by a

difference of eighteen responses. On the opposite side, at different importance rates of the Failure to comply with the quality specifications factor, the Flexibility and cooperation when resolving the delay factor has the highest importance by a difference of fifteen responses. This means that the Failure to comply with the quality specifications is more significant than the Flexibility and cooperation when resolving delays.

Table 8 shows the relationship between the Failure to comply with the quality specifications and the delay factors. As shown in the table there is no response when the Failure to comply with the quality specifications has the highest importance and the delay has moderate importance. Also at different importance rates of the delay factor, the Failure to comply with the quality specifications factor has the highest importance by a difference of 18 responses. On the opposite side, at different importance rates of the Failure to comply with the quality specifications, the delay has the highest importance by a difference of 15 responses. This means that the Failure to comply with the quality specifications is more significant than the delay.

Table 9 shows the relationship between the Failure to comply with the quality specifications and the Reputation factors. As shown in the table there is no response when the Failure to comply with the quality specifications has the lowest importance and the Reputation has a moderate importance. Also at different importance rates of the Reputation, the Failure

**Table 3** Frequencies of importance level for the different factors.

| ID  | Factor                                                        | Less | ... | ... | ... | Most | Mean score |
|-----|---------------------------------------------------------------|------|-----|-----|-----|------|------------|
|     |                                                               | 1    | 2   | 3   | 4   | 5    |            |
| CC1 | Cost overruns                                                 | 3    | 2   | 4   | 7   | 13   | 3.86       |
| CC2 | Flexibility in payment terms and conditions                   | 0    | 2   | 8   | 10  | 9    | 3.90       |
| CC3 | Tender price                                                  | 1    | 1   | 3   | 11  | 13   | 4.17       |
| CC4 | Sub-contractor's difficulty in reimbursement                  | 1    | 1   | 6   | 9   | 12   | 4.03       |
| CC5 | Failure to complete contract                                  | 3    | 0   | 1   | 7   | 18   | 4.28       |
| CC6 | Financial stability                                           | 2    | 1   | 6   | 11  | 9    | 3.83       |
| CC7 | Financial references                                          | 4    | 5   | 10  | 5   | 5    | 3.07       |
| QC1 | Quality                                                       | 0    | 1   | 2   | 13  | 13   | 4.31       |
| QC2 | Sub-contractor's poor management ability                      | 2    | 2   | 6   | 9   | 10   | 3.79       |
| QC3 | QA/QC programs                                                | 2    | 3   | 10  | 6   | 8    | 3.52       |
| SC1 | Energy saving materials and installations                     | 7    | 3   | 11  | 8   | 0    | 2.69       |
| SC2 | Poor competency of laborers                                   | 0    | 2   | 9   | 11  | 7    | 3.79       |
| SC3 | Experience of technical personnel                             | 0    | 2   | 3   | 18  | 6    | 3.97       |
| SC4 | Decorum, conduct and non-disruptiveness of the staff          | 1    | 1   | 17  | 7   | 3    | 3.34       |
| SC5 | Prevention of vandalism                                       | 2    | 0   | 7   | 12  | 8    | 3.83       |
| SC6 | Cooperation with the other subcontractors on the project      | 1    | 2   | 10  | 12  | 4    | 3.55       |
| SC7 | Creativity and innovation                                     | 0    | 4   | 12  | 9   | 4    | 3.45       |
| SC8 | Labor force retention                                         | 3    | 2   | 11  | 8   | 5    | 3.34       |
| SF1 | Jobsite cleanliness during projects and upon leaving jobsites | 3    | 4   | 8   | 10  | 4    | 3.28       |
| SF2 | Prosecution due to unlawful disposal of construction waste    | 3    | 5   | 5   | 13  | 3    | 3.28       |
| SF3 | Safety consciousness on the job site                          | 0    | 3   | 6   | 8   | 12   | 4.00       |
| IR1 | Onsite plant maintenance and repair programs                  | 0    | 2   | 12  | 11  | 4    | 3.59       |
| IR2 | Responsiveness to warranty issues                             | 3    | 5   | 8   | 9   | 4    | 3.21       |
| IR3 | Not buying insurance for major equipment and employees        | 3    | 3   | 10  | 10  | 3    | 3.24       |
| DR1 | Suppliers incompetency to deliver materials on time           | 1    | 2   | 2   | 7   | 17   | 4.28       |
| DR2 | Disputes and arbitration                                      | 1    | 2   | 2   | 7   | 17   | 3.97       |
| DR3 | Failure to comply with the quality specifications             | 1    | 2   | 2   | 6   | 18   | 4.31       |
| DR4 | Lack of readily available utilities on site                   | 1    | 7   | 8   | 7   | 6    | 3.34       |
| DR5 | Risk avoidance                                                | 2    | 2   | 5   | 11  | 9    | 3.79       |
| TC1 | Flexibility and cooperation when resolving delays             | 0    | 0   | 4   | 10  | 15   | 4.38       |
| TC2 | Delay                                                         | 1    | 0   | 2   | 11  | 15   | 4.34       |
| TC3 | Length of time in industry                                    | 0    | 2   | 7   | 13  | 7    | 3.86       |
| TC4 | Flexibility in critical activities                            | 0    | 1   | 7   | 11  | 10   | 4.03       |
| TC5 | Flexibility in the noncritical activities                     | 4    | 5   | 8   | 6   | 6    | 3.17       |
| EC1 | Reputation                                                    | 0    | 0   | 4   | 10  | 15   | 4.38       |
| EC2 | Being familiar with the area or being domestic                | 0    | 2   | 7   | 13  | 7    | 3.86       |
| EC3 | Knowledge of construction regulations                         | 0    | 3   | 5   | 12  | 9    | 3.93       |
| EC4 | Volume of work committed                                      | 1    | 2   | 7   | 16  | 3    | 3.62       |
| EC5 | Experience in local area                                      | 0    | 1   | 9   | 15  | 4    | 3.76       |
| EC6 | Scale of projects completed                                   | 1    | 2   | 5   | 14  | 7    | 3.83       |
| TD1 | Tender quality                                                | 2    | 3   | 10  | 6   | 8    | 3.52       |
| TD2 | Willingness to tender                                         | 3    | 1   | 7   | 10  | 8    | 3.66       |
| OC1 | Site proximity                                                | 6    | 4   | 11  | 6   | 2    | 2.79       |
| OC2 | Ongoing work commitments                                      | 1    | 4   | 10  | 8   | 6    | 3.48       |
| OC3 | Physical resources                                            | 0    | 0   | 4   | 15  | 10   | 4.21       |
| OC4 | Relationships with the client                                 | 1    | 1   | 9   | 8   | 10   | 3.86       |

to comply with the quality specifications has the highest importance by a difference of 18 responses. On the opposite side, at different importance rates of the Failure to comply with the quality specifications, the Reputation has the highest importance by a difference of 15 responses. This means that the Failure to comply with the quality specifications is more significant than the Reputation.

As per Table 3, the mean score is calculated for each factor to determine the most important factors according to the expert's opinion. Each factor was given a score by the experts through the surveys, as this survey has 29 responds. Consequently, the mean score is calculated through getting the summation of the scores of each factor which were ranked

by the 29 experts, then dividing it by the total number of the respondents which is 29. Any factor that has a mean score greater than 4.00 is deemed important (see Fig. 1). So this study has 12 factors which are more important than the other 34 factors. These 12 factors, arranged from the most important to the least important are: Flexibility and cooperation when resolving delays (TC1) and Reputation (EC1) with the same score, followed by delay (TC2); then Failure to comply with the quality specifications (DR3) and Quality (QC1) with the same score; Suppliers incompetency to deliver materials on time (DR1) and Failure to complete contract (CC5) with the same score; Physical resources (OC3); Tender price (CC3); Contractor's difficulty in

**Table 4** Identification of significant factors.

| Factor                                                        | Mean score | SD   | p-Value | State           |
|---------------------------------------------------------------|------------|------|---------|-----------------|
| Cost overruns                                                 | 3.86       | 1.36 | 0.004   | Significant     |
| Flexibility in payment terms and conditions                   | 3.90       | 0.96 | 0.000   | Significant     |
| Tender price                                                  | 4.17       | 1.01 | 0.000   | Significant     |
| Sub-contractor's difficulty in reimbursement                  | 4.03       | 1.05 | 0.000   | Significant     |
| Failure to complete contract                                  | 4.28       | 1.27 | 0.000   | Significant     |
| Financial stability                                           | 3.83       | 1.16 | 0.001   | Significant     |
| Financial references                                          | 3.07       | 1.24 | 0.547   | Not significant |
| Quality                                                       | 4.31       | 0.76 | 0.000   | Significant     |
| Sub-contractor's poor management ability                      | 3.79       | 1.21 | 0.003   | Significant     |
| QA/QC programs                                                | 3.52       | 1.20 | 0.051   | Not significant |
| Energy saving materials and installations                     | 2.69       | 1.11 | 0.244   | Not significant |
| Poor competency of laborers                                   | 3.79       | 0.92 | 0.000   | Significant     |
| Experience of technical personnel                             | 3.97       | 0.77 | 0.000   | Significant     |
| Decorum, conduct and non-disruptiveness of the staff          | 3.34       | 0.81 | 0.073   | Not significant |
| Prevention of vandalism                                       | 3.83       | 1.07 | 0.001   | Significant     |
| Cooperation with the other subcontractors on the project      | 3.55       | 0.92 | 0.008   | Significant     |
| Creativity and innovation                                     | 3.45       | 0.88 | 0.025   | Significant     |
| Labor force retention                                         | 3.34       | 1.15 | 0.200   | Not Significant |
| Jobsite cleanliness during projects and upon leaving jobsites | 3.28       | 1.17 | 0.339   | Not significant |
| Prosecution due to unlawful disposal of construction waste    | 3.28       | 1.13 | 0.106   | Not significant |
| Safety consciousness on the job site                          | 4.00       | 0.98 | 0.000   | Significant     |
| Onsite plant maintenance and repair programs                  | 3.59       | 0.83 | 0.001   | Significant     |
| Responsiveness to warranty issues                             | 3.21       | 1.15 | 0.200   | Not significant |
| Not buying insurance for major equipment and employees        | 3.24       | 1.06 | 0.119   | Not significant |
| Suppliers incompetency to deliver materials on time           | 4.28       | 1.11 | 0.000   | Significant     |
| Disputes and arbitration                                      | 3.97       | 1.09 | 0.000   | Significant     |
| Failure to comply with the quality specifications             | 4.31       | 1.12 | 0.000   | Significant     |
| Lack of readily available utilities on site                   | 3.34       | 1.19 | 0.125   | Not significant |
| Risk avoidance                                                | 3.79       | 1.18 | 0.002   | Significant     |
| Flexibility and cooperation when resolving delays             | 4.38       | 0.73 | 0.000   | Significant     |
| Delay                                                         | 4.34       | 0.91 | 0.000   | Significant     |
| Length of time in industry                                    | 3.86       | 0.88 | 0.000   | Significant     |
| Flexibility in critical activities                            | 4.03       | 0.86 | 0.000   | Significant     |
| Flexibility in the noncritical activities                     | 3.17       | 1.32 | 0.670   | Not significant |
| Reputation                                                    | 4.38       | 0.73 | 0.000   | Significant     |
| Being familiar with the area or being domestic                | 3.86       | 0.86 | 0.000   | Significant     |
| Knowledge of construction regulations                         | 3.93       | 0.96 | 0.001   | Significant     |
| Volume of work committed                                      | 3.62       | 0.91 | 0.000   | Significant     |
| Experience in local area                                      | 3.76       | 0.75 | 0.000   | Significant     |
| Scale of projects completed                                   | 3.83       | 1.01 | 0.000   | Significant     |
| Tender quality                                                | 3.52       | 1.20 | 0.051   | Not significant |
| Willingness to tender                                         | 3.66       | 1.23 | 0.014   | Significant     |
| Site proximity                                                | 2.79       | 1.23 | 0.364   | Not significant |
| Ongoing work commitments                                      | 3.48       | 1.11 | 0.024   | Significant     |
| Physical resources                                            | 4.21       | 0.67 | 0.000   | Significant     |
| Relationships with the client                                 | 3.86       | 1.06 | 0.000   | Significant     |

**Table 5** Failure to comply with the quality specifications vs Quality crosstab.

|         |   | Failure to comply with the quality specifications |   |   |   |    | Total |
|---------|---|---------------------------------------------------|---|---|---|----|-------|
|         |   | 1                                                 | 2 | 3 | 4 | 5  |       |
| Quality | 1 | 0                                                 | 0 | 0 | 0 | 0  | 0     |
|         | 2 | 0                                                 | 0 | 1 | 0 | 0  | 1     |
|         | 3 | 0                                                 | 0 | 0 | 0 | 2  | 2     |
|         | 4 | 1                                                 | 2 | 1 | 4 | 5  | 13    |
|         | 5 | 0                                                 | 0 | 0 | 2 | 11 | 13    |
| Total   |   | 1                                                 | 2 | 2 | 6 | 18 | 29    |

reimbursement (CC4) and Flexibility in critical activities (TC4) with the same score; and Safety consciousness on the job site (SF3).

The order of these factors is an indicator to the current trend of the sub-contractor selection process in the construction field. Since several factors have equal scores, there are

**Table 6** Failure to comply with the quality specifications vs Supplier's incompetency to deliver materials on time crosstab.

|                                                     | Failure to comply with the quality specifications |   |   |   |   |    | Total |
|-----------------------------------------------------|---------------------------------------------------|---|---|---|---|----|-------|
|                                                     | 1                                                 | 2 | 3 | 4 | 5 |    |       |
| Suppliers incompetency to deliver materials on time | 1                                                 | 1 | 0 | 0 | 0 | 0  | 1     |
|                                                     | 2                                                 | 0 | 2 | 0 | 0 | 0  | 2     |
|                                                     | 3                                                 | 0 | 0 | 0 | 1 | 1  | 2     |
|                                                     | 4                                                 | 0 | 0 | 2 | 2 | 3  | 7     |
|                                                     | 5                                                 | 0 | 0 | 0 | 3 | 14 | 17    |
| Total                                               |                                                   | 1 | 2 | 2 | 6 | 18 | 29    |

**Table 7** Flexibility and cooperation when resolving delays vs Failure to comply with the quality specifications crosstab.

|                                                   | Flexibility and cooperation when resolving delays |   |   |   |    |    | Total |
|---------------------------------------------------|---------------------------------------------------|---|---|---|----|----|-------|
|                                                   | 1                                                 | 2 | 3 | 4 | 5  |    |       |
| Failure to comply with the quality specifications | 1                                                 | 0 | 0 | 0 | 1  | 0  | 1     |
|                                                   | 2                                                 | 0 | 0 | 1 | 0  | 1  | 2     |
|                                                   | 3                                                 | 0 | 0 | 0 | 1  | 1  | 2     |
|                                                   | 4                                                 | 0 | 0 | 3 | 1  | 2  | 6     |
|                                                   | 5                                                 | 0 | 0 | 0 | 7  | 11 | 18    |
| Total                                             |                                                   | 0 | 0 | 4 | 10 | 15 | 29    |

**Table 8** Flexibility and cooperation when resolving delays vs delay.

|                                                   | Delay |   |   |   |    |    | Total |
|---------------------------------------------------|-------|---|---|---|----|----|-------|
|                                                   | 1     | 2 | 3 | 4 | 5  |    |       |
| Failure to comply with the quality specifications | 1     | 0 | 0 | 1 | 0  | 0  | 1     |
|                                                   | 2     | 0 | 0 | 0 | 1  | 1  | 2     |
|                                                   | 3     | 0 | 0 | 0 | 1  | 1  | 2     |
|                                                   | 4     | 0 | 0 | 1 | 3  | 2  | 6     |
|                                                   | 5     | 1 | 0 | 0 | 6  | 11 | 18    |
| Total                                             |       | 1 | 0 | 2 | 11 | 15 | 29    |

**Table 9** Flexibility and cooperation when resolving delays vs Reputation.

|                                                   | Delay |   |   |   |    |    | Total |
|---------------------------------------------------|-------|---|---|---|----|----|-------|
|                                                   | 1     | 2 | 3 | 4 | 5  |    |       |
| Failure to comply with the quality specifications | 1     | 0 | 0 | 0 | 1  | 0  | 1     |
|                                                   | 2     | 0 | 0 | 0 | 2  | 0  | 2     |
|                                                   | 3     | 0 | 0 | 1 | 0  | 1  | 2     |
|                                                   | 4     | 0 | 0 | 1 | 3  | 2  | 6     |
|                                                   | 5     | 0 | 0 | 2 | 4  | 12 | 18    |
| Total                                             |       | 0 | 0 | 4 | 10 | 15 | 29    |

eight levels of ranking of the 12 factors. Among the two most important factors is Reputation. This factor is one that many contractors highly depend on when deciding whether or not a sub-contractor will be chosen. For instance, as highlighted by Hartmann et al. [4], Reputation counts as a significant indicator of the sub-contractor's future work. This occurs through looking at a sub-contractor's past experience in order to determine the degree of professionalism and experience in matters such as quality, cooperation and general attitude in a project besides the technical know-how [4]. Consequently, this was supported by this study; as Reputation is considered

a highly significant factor, on which other selection factors can be based according to the expert's opinion.

Same applies to Flexibility and cooperation when resolving delays factor; as it also came as the first most important factor of twelve factors. A sub-contractor's attitude in a project is crucial especially because he gets to deal with several parties. Therefore, cooperation and flexibility are essential for the project's success; according to Hartmann et al. [4] the extent to which sub-contractors "fulfill agreements" and the extent to which they "proactively solve and prevent problems" has its direct impact on the project's "operational efficiency" [4]

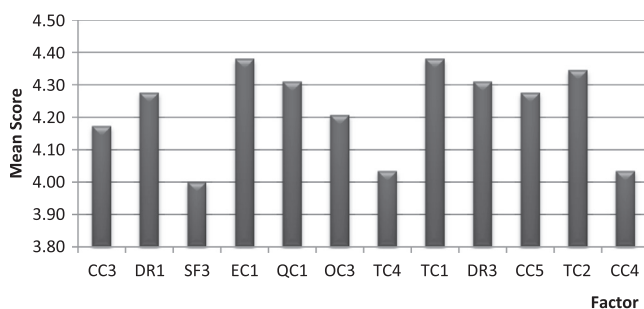


Fig. 1 Mean score of important factors.

Therefore, the extent to which sub-contractors handle delays falls under the same umbrella; which was proven in this study. Moreover, as highlighted by many of the previous studies, the tender price should not be the main criterion based on which the selection process occurs. However, in real life it is still an important factor in the sub-contractor's selection process. This was highly supported in this study; as the tender price factor is among the 12 most important factors, yet it came in the sixth level out of the eight levels of their ranking. Furthermore, surprisingly cost overruns factor is not one of the 12 top factors; its mean score came out to be 3.86. This shows that price and cost are not regarded by main contractors as the best indicators of the most adequate sub-contractor in their decision making process. From the frequency table, it is concluded that the Quality factor and delay factor are the most important factors because 89.66% of the respondents gave them the scores 4 and 5.

As shown in the crosstabs tables, these tables create a comparison between each two factors of the most important factors in this study. The comparisons done mainly show which factor dominates the other; as a comparison between the total numbers of respondents of both factors is done. For instance if we have factor A and factor B, and at score 4 the total number of respondents of factor B is 7, the distribution of these respondents on the different scores of factor A is noticed. From the previous tables of the crosstabs, it is concluded that the significance of the factors related to Cost criteria, such as Tender price, is not as high as other factors, such as Failure to complete the contract. In determination of the significant factors, the mean score and p-value are used for determining the significant factors. Any factor of the forty six factors is considered significant if its mean score is greater than or equals 3.00 and its p-value less than 0.05. In some cases however, a factor can be considered as not significant even if its mean score is greater than 3.00 and this occurs in case its p-value is greater than 0.05. According to this table, thirteen factors can be identified as not significant factors because their p-value is greater than 0.05.

### Summary and conclusions

This paper introduces ten criteria and their 46 factors. These factors are used for the selection of sub-contractors. They were

collected from previous studies. This study presents a survey which was done to determine the mean score for each factor which was conducted with 29 experts in the construction field. From the survey, the twelve factors were determined as important. These factors have a mean score more than 4.00. These factors are: Flexibility and cooperation when resolving delays (TC1) and Reputation (EC1) with the same score, followed by delay (TC2); then Failure to comply with the quality specifications (DR3) and Quality (QC1) with the same score; Suppliers incompetency to deliver materials on time (DR1) and Failure to complete contract (CC5) with the same score; Physical resources (OC3); Tender price (CC3); Contractor's difficulty in reimbursement (CC4) and Flexibility in critical activities (TC4) with the same score; and Safety consciousness on the job site (SF3). The paper presented statistical analysis of survey responses including: cross-tabulation calculations, frequency calculations, and the significant factors. The cross-tabulation calculations represent the comparison between two factors according to their scores from the first survey. The frequency calculations determine the number of the response for each score ranking defined in the survey. Using the mean score for each factor and calculating the p-value by using the SPSS software, each factor used in the questionnaire is classified as significant or not. Any factor that has a p-value of less than 0.05 is considered a significant one.

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