FORECASTING MODEL TO PREDICT PROJECT SUCCESS BASED ON THE CONTRACTORS' CHARACTERISTICS

by

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Approval Signatures

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Abstract

Successful delivery of construction projects requires completing the projects on time and within budget, while ensuring the delivery of a quality product. Most construction projects experience delays, cost overruns and quality problems. In a country like the United Arab Emirates (UAE), where high development activities are happening rapidly, it is very dangerous for the overall economy if repeated failures in construction projects remain unsolved or even uninvestigated. The selection of the right contractor has a direct and significant impact on the success of construction projects. There is a need to select the appropriate contractor who is capable of increasing the chances of the project's success. Relying on the selection of the lowest bidder is misleading. The research objective is to develop a model that predicts the project's success based on the contractor's characteristics, be they financial or non-financial. This will reduce the risks associated with the process extensively. Sixteen key characteristics, that have a direct impact on project success, were identified through an extensive literature review. Those sixteen characteristics were grouped into four main categories: the firm's capacity, past experience and past performance, project management capabilities and sustainability and technology practices. A survey, using the Analytic Hierarchy Process (AHP), was conducted to prioritize those characteristics and link them to the success criteria. Success criteria were limited to cost, time and quality. Forty-five respondents completed the survey including owners, contractors and consultants. The results indicated that respondents prefer financial (bid price) slightly over non-financial characteristics (0.513 and 0.487, respectively). As for the non-financial characteristics, the results show that the main categories are ranked as follows: project management capabilities, past experience and past performance, sustainability and technology practices and firm's capacity. Four out of the top five characteristics were found to be part of the project management capabilities group. In terms of project success criteria, the results are as follows: quality (0.413), cost (0.317), and time (0.270). Through relating contractor characteristics and financial factors to the project success criteria, a forecasting model has been developed to predict project success based on the given parameters. A case study is also presented to show the application of the proposed model.

Keywords: ***Contractors' selection; project success; construction industry; UAE***

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List of Abbreviations

AHP	Analytic Hierarchy Process
CIDA	Construction Industry Development Agency
CSR	Corporate Social Responsibility
GDP	Gross Domestic Product
LEED	Leadership in Energy and Environmental Design
UAE	United Arab Emirates

Chapter 1. Introduction

When the public sector launches any bidding auction, the lowest price bidder will usually win the bid and proceed with the project. Although this type of selection will yield to a competitive market price, it will not always ensure project success. Cost is an essential factor of project success but it's not the only factor. Time and quality are also bases of a project success. The awareness of non- price criteria has started gaining more recognition within the industry recently [1]. Small and new companies/contractors starve to have any project and accept getting zero profit, or even a small loss, just to build their reputation and portfolio within the market. This may lead to project failure as the contractor may sacrifice safety or quality aspects to cut costs and minimize losses.

1.1 Overview

The United Arab Emirates (UAE) has a unique construction industry. The huge construction boom, that the UAE has experienced, transformed the UAE from a desert to a developing country with unique megaprojects that stand as world landmarks. Burj Khalifa, the tallest tower in the world, and Dubai mall, the world's biggest shopping mall, are examples of the magnificent transition that the UAE construction industry encountered. Since the moment the UAE Government has decided not to be an oil dependent nation, a huge focus was laid on tourism; many commercial and industrial activities have been established [2]. The major boom, that happened between 1996 and 2007, created an evolution in the construction industry including having the highest construction activity per square kilometer in the world in 2006 [3] [4]. A four hundred percent increase on land projection area was experienced in the UAE between 1990 and 2010 [5]. According to the records of Dubai Chamber of Commerce and Industry, the construction industry makes 10.3% of the UAE GDP [6]. All of those facts about the UAE construction industry emphasize the importance of this sector for the UAE overall economy. A study sampled eight hundred sixty-six residential projects and found that fifty four percent experienced delay or even stop [5]. Consecutive failures in construction projects may threaten the construction sector in the UAE, not only through reducing investment and development but also through creating pressure on the whole economy of the country. A model that predicts construction project success based on both the contractors' characteristics and the financial factors would be very helpful in

such an environment, since it leads to a reduction in risks and an increase in decision makers' confidence.

In this thesis, contractors' characteristics will be identified, analysed and related to project success. This will serve as a prequalification check for bidders and will result in a better selection which will save time, money and effort. Moreover, this study will reinforce our selection of a certain contractor by including non-price criteria in analysis and evaluation. Furthermore, this model will also help in increasing the probability of project success and create a fair competition among bidders since they all share the same characteristics. Through this thesis, the first step was the identification of key characteristics that have a direct relation to the project success. Then, success factors were defined and assessed. Finally, using AHP, a survey was distributed to link the contractor's characteristics to success factors and provide a prioritization factor for both the contractor's characteristics and the success factors. The results of the survey were used to develop a mathematical model that relates characteristics and project success. Moreover, the model considered the financial factor while evaluating each of the contractors in order to help the evaluator get the best fit contractor for the job.

1.2 Statement of the Problem

The selection of the contractor of the basis of the lowest price seems to be an outdated technique or method. This technique neglects some of the non-price factors that are essential for project success. Success factors, such as quality and time, make a vital portion of the project success phenomenon. Focusing only on the cost aspect will definitely lead to serious failures in the projects. Moreover, while selecting contractors, decision makers don't have the proper tools to evaluate the contractors based on the characteristics they have. This will lead to a wrong selection of the contractor causing a lot of difficulties during different phases of the project and might increase the probabilities of projects failure. Continuous project failures and the lack of ability to predict the success of the project have a negative impact on the investment. Those factors will certainly affect the UAE construction sector, and will surely have an impact on the overall UAE economy.

1.3 Research Objectives

The main objective of this thesis is to develop a mathematical model to predict project success based on contractors' characteristics and financial factors. The detailed objectives are as follows:

1 Identify and evaluate key criteria for selecting contractors
2 Identify and evaluate project success criteria
3 Develop a prediction model that relates contractors' characteristics to project success and provide a model that will govern both financial and nonfinancial factors while evaluating a contractor.

1.4 Methodology

In order to fulfill objective one, which is the identification and evaluation of the most critical contractors' selection criteria in the UAE construction industry, such criteria were gathered from previous research done through extensive literature review. Once the contractors' selection criteria are gathered, such criteria were shortlisted according to the frequency of appearance on previous research. The shortlisted criteria were then grouped into main categories based on the common characteristics within the criteria. Moreover, such criteria were ranked upon their importance and priority according to the UAE construction community. A survey was conducted to assess and rank those characteristics. Since the survey assesses multi-criteria, the Analytic Hierarchy Process (AHP) was implemented to help in the decision making process. AHP techniques developed a weighted factor for each of the criterion allowing for the ranking of the criteria. AHP created pairwise comparison between the criteria, which will reduce the complexity of the decision. Once the survey is prepared, it was distributed among contractors, consultants, and owners. The surveys were collected then analyzed using expert choice software. Expert choice is a computer aided software that helps in the decision making process for multi-criteria. The software utilizes AHP model features to prioritize the criteria.

To achieve objective two, the project success criteria were identified and evaluated to obtain the most essential criteria for construction project success. Through literature review, the project success criteria were gathered based on previous research. The criteria were then shortlisted to make sure that the only critical success criteria are involved in the study. For practicality reasons, and after extensive literature review, the

success criteria were limited to cost, time and quality success. During the same survey that was distributed, those success criteria such prioritized based on their importance for project success. AHP was also used to assess the project success criteria. Once the data were collected from the filled surveys, expert choice software was used for the analysis.

Throughout the survey results which used the AHP techniques, the effect of each of the contractor's characteristics on each of the success factors were obtained. This data along the prioritization records obtained from the same survey were used to develop a forecasting model that will predict the project success based on contractor's characteristics and financial factors. The model included both the financial and non-financial aspects for better evaluation. Financial factors within the model are subjective to the evaluator while the nonfinancial factors are obtained through number of mathematical equation. Through those equations, each of the main categories is related to each of the success factors (cost, time and quality). The summation of the results provides us with the nonfinancial factors weight. The financial and nonfinancial weights are added to each other based on the prioritization obtained from the survey in order to have a success score that determines the best fit contractor for the particular job.

1.5 Thesis Organization

The following chapters are organized as follows: chapter two provides literature review on the main objectives of this thesis such as contractor selection methods, contractor selection criteria, project success criteria and the relationship between contractor characteristics and success. Chapter three includes the identification of the contractors' characteristics, explanation of each of the categories and the characteristics. The data analysis obtained from the surveys are discussed in Chapter four. Chapter five presents the model and a practical implementation of the forecasting model on a mock case study to test the effectiveness of the new model. Finally, chapter six concludes the thesis and outlines the future work.

Chapter 2. Background and Literature Review

2.1 Contractor Selection Methods

One of the main challenges in construction projects is the selection of the contractor. Usually, the client will commission a contractor to construct or execute the project as per the drawings and specifications prepared by the architects or consulting firm. If an incompetent contractor is hired, the chances of delays will increase; poor quality will result with a great possibility of cost overrun. All of those three outcomes indicate that the project is experiencing a failure. Direct appointment is one of the contractor selection methods [7]. The client, in this case, will directly appoint the contractor based on past projects they worked together, well-known technical qualifications and similar projects that the contractor accomplished perfectly [8]. Others looked at the disadvantages of this procurement method [9]. The main weakness of this method is that it neglects the price completeness causing the project to cost mostly above the average.

Most owners or developers will use a procurement method that focuses on cost or price. Selecting the lowest bidder is a common practice within the industry. Some researchers believe that focusing only on one aspect such as price in evaluating a bid, is one of the main causes of project delivery problems. This belief can be justified by the fact that any of the contractors that do not have enough work will surely submit a low bid just to protect their business [10]. According to Hatush and Skitmore [11], such contractors will tend later to ask for more money from the client at the actual construction phase through variations and claims. In this case, selecting the lowest bidder is too risky.

Other procurement methods were developed to help in minimizing the risks of the contractor selection by accounting for more factors than only the bid price. One of the proposed methods was to implement Analytic Hierarchy Process (AHP) to select the most appropriate contractor. The method ranks the selection criteria based on their importance, then the contractors will be prioritized according to their scores in each of the listed criteria. The one with the highest score will win the bid [12]

2.2 Contractor Selection Criteria

Previously, the only criterion for a contractor selection was price. In the past two decades, several papers have discussed the importance of evaluating the contractor against both price and non-price criteria in order to select the “fit” contractor that will meet the project’s requirements, budget and time [13] [14]. Russell and Skibniewski [15] suggested considering factors such as reputation, past performance, financial stability, technical experience, workload, capacity when evaluating a contractor. They developed a software that evaluates contractors based on those criteria. Later, using spearman rank correlation, twenty factors and sixty-seven sub factors were ranked be one hundred ninety-two of the professionals in the field via a questionnaire [13]. The study showed that financial stability, past performance and experience were the most important factors. CIDA [16] suggested that criteria like skill formation, technical ability, quality assurance, financial capability, time performance, health and safety, and human resource management are the basis of any contractor selection evaluation. According to Hatush and Skitmore [17], financial soundness, technical ability, managerial capability, safety, and reputation are essential characteristics that must be considered when conducting contractor evaluation. Cheng and Li [14] used eight criteria to evaluate contractors. They included past experience, tender price, resources, workload, safety management, past performance financial capability and past relationship. They used AHP to rank their criteria from the highest to lowest in terms of importance. One obvious note was that the selection criteria were approached differently by the different positions within the industry. In order to investigate those different perceptions, Singh and Tiong [18] had a sample of one hundred twenty-eight experts within the industry with different backgrounds/roles. The sample included quantity surveyors, developers, and contractors; both public and private clients participated in a questionnaire to select from 102 contractor selection criteria. Contractor experience and qualification of the project manager and management staff on a similar project within the last three years was viewed as the most critical criteria to examine [18]. El-Sayegh [19] also categorized the selection criteria into four categories based on extensive literature review. Each of them contains five characteristics that have something in common. Fifty-two completed survey and AHP were conducted to obtain the weight of each criteria. The most critical criteria weretechnical ability, shortest completion time, the ability to complete the project

within budget, performance on previous projects and general contracting experience [19].

2.3 Project Success Criteria

One of the most efficient techniques to improve and develop, in project management, is to learn from previous successes and failures [20]. Not agreeing on one definition that defines the success of the project made the whole construction process hard to evaluate to pave the way for further improvements since the evaluator will not have any guidelines that define how to look at the outcome of the process. One simple reason that made it hard to create one exact definition of the project success in construction is that, in the construction industry, we have diversity of professions and responsibilities, and each of them will look at the success from his/her perspective. For example, engineers put emphasis on structure issues and practicality of the design while architects focus on the visuals and appearance [21]. Searching through the literature showed that many definitions have been proposed. De Wit [22] stated that there are two different concepts: project success and project management/performance success. The project success is related to achieving all objectives of the project. Project management/ performance success, on the other hand, deals with evaluating performance against cost, time and quality. Cooke-Davies [23] and Morris & Hough [24] suggested that the results of the project success are only shown after the project completion while project management/ performance success can be assessed at any time during the project life. To study project success, project success factors and criteria should be identified clearly [25]. Both project success factors and criteria should be looked at together as it will be meaningless to observe one aspect alone [26]. To start with the success factors, Martin [27] selected identification of project objective and goals to be one of the essential factors. Cleland & King and Pinto [28] and Slevin [29] suggested that the main factor in project success is to get general and top management support. Moreover, communication, teamwork and leadership are factors that help to 17ulfil the project objectives successfully [30] [31]. On the other hand, many researchers agreed that time, cost and quality are the cornerstone of project success criteria [32] [33] [34]. Baccarini [35] suggested that user satisfaction, owner's strategy, profitability, and market share along with time, cost, quality, project management process and stakeholders' satisfaction are major criteria that evaluators should investigate. Lim & Mohammad

[36] categorized the criteria into two categories: micro and macro. Mirco criteria include time, cost, quality, performance and safety while Macro criteria consist of time, satisfaction, utility, and operation. Other researchers also classified the criteria into subjective measures and objective measures. Subjective measures deal with quality, functionality and satisfaction of different project participants. Time, cost, safety and environment are considered objective measures [37]. Al-Tmeemy et al. [32] created a model in which they classified the project success into three groups: project management success, product success, and market success. Each of the groups contained criteria that build up the category success. Adherence to quality targets, budget and schedule are sorted out as project management success. Product success is associated with technical specification, customer satisfaction and functional requirements. In addition, market success is directly related to criteria such as revenue and profit, market share, reputation and competitive advantage. Such criteria and classifications are derived from questionnaire responses of one hundred fifty-one Malaysian construction experts [32].

2.4 Relationship between Contractor Characteristics and Success

Hatush and Skitmore [38] interviewed six construction professionals and two validators to study the relationship between twenty contractor characteristics and project success. Project success was defined in terms of three main criteria: cost, time and quality. Moreover, they used PERT to analyze the inputs of the experts and to calculate the expected mean and variance for each characteristic /criterion and their impact on each of the three success factor using 90%, 95% and 99% confidence Intervals. The interview results showed that past failures, financial stability, credit ratings were the most essential characteristics to consider while management safety accountability was given the least importance [38]. This study helped a lot in quantifying the effects of the criteria on the success factors, but it did not mention if these perceptions were universal or just for the examined projects in the specified region- Australia. Doloi [39]defined forty-three characteristics which were later categorized ten criteria. The influence of such criteria on project success were then determined through a survey for selected projects. Sixty-seven experts responded to the questionnaire then a factor analysis were performed. Seven factors were selected to be the most influential characteristics that have a considerable impact on project success. They include soundness of business and workforce, planning and control, quality

management, past performance, risk management, organizational capability, and commitment and dedication. A multiple regression model was used later to interpret the relation between the characteristics and the project success. The results showed that working capital, time in business, past success, work methods and technical expertise influence the project cost, time and quality significantly. A sample of 67 professionals for a regression model is relatively small, taking into consideration that the study obtained responses from four different professions within the field only, which may cause some coverage error [39]. Both studies did not investigate the client opinion about the relation such criteria have to the project success. Moreover, none of the papers defined the success criteria clearly and how the type of the project can affect the relation between the criteria and success.

Chapter 3. Contractors' Characteristics Identification

3.1 Overview

In order to identify and evaluate key criteria for selecting contractors in the UAE construction industry, contractors' selection criteria were gathered from previous research through extensive literature review. Seventy criteria were collected from the literature review and were grouped into four main groups. Moreover, new criteria were added based on the field experience that was not accounted for in the literature. On three iterations, the seventy criteria were shortlisted based on how frequent they were repeated in the literature and on whether such criteria can be measured and evaluated or not. After shortlisting, we had sixteen criteria that were grouped into four main groups. The criteria were grouped into main categories based on the common characteristics between the criteria. Those four categories mainly cover all aspects that a construction firm can be evaluated against. The four main groups are: firm's capacity, past experience and past performance, project management capabilities, sustainability and technology practices. The firm's capacity will assess the company internal strength and the availability of the resources to fulfill the project requirement. The past experience and past performance will evaluate the firm's history and reputation within the market. Furthermore, project management capabilities will reflect how the company is organized from within and whether it has the suitable knowledge and procedures to monitor and regulate all construction activities within time, budget and desired quality. Finally, the sustainability and technology practices will ensure that this firm is coping with new technologies available in the market; it will also assess the commitment of the firm to perform using the latest technology which will eventually lead to better and long-lasting construction solutions.

3.2 Group 1 - Firm's Capacity

Firm's capacity covers all aspects related to the availability and stability of firm's resources which reflect the internal strength of the company. Current workload, financial stability, equipment availability, and labor availability are the criteria that fall under the firm's capacity group. The current workload criterion ensures that the resources and financial resources needed for the evaluated project are available and will not be allocated to any other project due to excess workload. It also evaluates the current open commitments along with the expected new projects against the overall available

resources. The financial stability of the firm is a good indicator of the firm's strength. It guarantees that the firm can fund the project either by its own resources or through bank arrangement. This criterion can be checked through various methods such as the financial and balance sheet statements, or through the ability to obtain bank finance arrangement. Equipment availability also represents the firm's ability to perform well in a project. A firm without adequate equipment will definitely experience a lot of struggles to complete the project. This criterion can be examined through a detailed analysis of the number of estimated equipment needed compared to the available ones, the condition of the equipment, the suitability of the equipment for this particular project and the ability for the firm to rent the missing equipment needed to fulfill the project requirements. Labor availability must be checked whenever firm's capacity is evaluated. A firm without enough labor will never achieve the desired quality within the budget and the time allocated. Moreover, lack of enough labor will reflect badly on the ability of the firm to control and manage the project. Table 3.1 represents the criteria that fall in the "contractors' characteristics" group1 along with their definitions and citations.

Table 3.1 Group 1 – Contractors' Characteristics Identification

	Criteria	Definition	Citation	Frequency
Group 1	Firm's Capacity	All aspects related to the firm's resources availability and stability which will reflect the internal strength of the company	[12] [13] [14] [15] [40] [41]	6
	Equipment Availability	Detailed analysis of the number of estimated equipment needed compared to the available ones, the Condition of the equipment, the suitability of the equipment for this particular project and the ability for the firm to rent the missing equipment needed to fulfill the project requirements.	[13] [12] [14] [17] [18] [38] [40] [41] [42]	9
	Current Workload	Evaluate the Current open commitments along with the expected new projects against the overall available resources	[12] [13] [14] [15] [18] [40] [41] [42]	8
	Labor Availability	Evaluate whether the firm have enough labors to achieve the desired quality within the budget and the time allocated	[12] [13] [14] [15] [17] [38] [40]	7
	Financial Stability	Grantees that the firm can fund the evaluated project either by its own resources or through bank arrangement	[12] [13] [14] [15] [17] [38] [40] [41] [42]	9

3.3 Group 2 - Past Experience and Past Performance

Past experience and past performance are factors that need to be considered to review the history of the company. The review process evaluates how well the company performed in previous projects, which will definitely be reflected in the company performance for the evaluated project. This group will include four criteria in order to assess the previous firm's experience and performance. Those criteria are: number and scale of completed projects, past performance (time and cost), past safety performance and past quality performance. Number and scale of completed projects show how much experience the company's management and staff have. If a company completed large number of projects within time, cost and specified quality, the tendency of the company to perform well in this project is much higher than a startup company. If a company has been involved in projects that are large in scale, and with a lot of technical details, they will surely have better understanding to the drawings and specs of the project, and it will eventually perform better than a company that worked on smaller, less detailed projects previously. Since previous history is a decisive factor for assessing a company's usual performance, then past performance with respect to both time and cost should be evaluated in order to predict the company performance in the current project. This criterion can be checked through evaluating the number of failures in completing a contract within time and cost over the number of total projects (failure ratio). Moreover, past safety performance is a key element in determining how organized the company is. It also reflects the company's commitment towards its employees and the society at large, which will certainly reflect on staff productivity. The available safety performance standards, the number of safety fines from municipality, the number of incidents, and existence of contractor safety program and director could give an indication on the past safety performance of the company. Similarly, past quality performance measures the quality of work produced by the company within the previously specified specs. This will increase the chances of completing the projects within the required specifications. Reviewing the quality of the completed projects, number of non-compliance reports issued per previous projects, and conducting site visits to current active projects might give an indicator on the past quality performance. Table 3.2 represents the criteria that fall in the "contractors' characteristics" group 2 along with their definitions and citations.

Table 3.2 Group 2 – Contractors' Characteristics Identification

	Criteria	Definition	Citation	Frequency
Group 2	Past Experience and Past performance	A review process that evaluates how well the company performed in previous projects which will definitely be reflected in the company performance for the evaluated project.	[12] [13] [14] [15] [17] [18] [38] [40] [42]	9
	Number and scale of completed projects	Evaluate how much of experience the company's management and staff have due to the exposure to different projects with different technical challenges	[12] [13] [14] [17] [18] [38] [40] [42]	8
	Past Performance (Time and Cost)	Evaluate how the firm performed in previous projects in meeting the deadlines and due dates along with completing the project within budget allocated	[13] [12] [14] [17] [41] [42]	6
	Past Safety Performance	Measures the firm's commitment towards their employees and society by considering safety measures at site by evaluating the safety record of the company in previous projects	[12] [14] [17] [18] [42]	5
	Past Quality Performance	Measures the quality of work produced by the company in previous projects within the previously specified specs	[13] [15] [17] [42]	4

3.4 Group 3 - Management Capabilities

Management capabilities group investigates the abilities of the firm to handle, manage and execute the project with high project management standards, techniques and tools. This group checks the company internal management capabilities by focusing on the following criteria: number and qualifications of key personnel, project controls capability, communication and documentation, and risk management capability. The number and qualifications of key personnel play a vital role in deciding how organized the company is. The staff qualification of the company gives a good indicator on how the company is going to manage the project. The more qualified the staff of the company are, the better its ability to manage projects and resolve issues on site. This can be examined by comparing available key personnel currently not assigned to any project to the number of key personnel needed for the project. Moreover, the existence of effective company training program can reflect how keen the firm is to improve their staff capabilities. Project control capability refers to the procedures and tools that the company uses to have a full control on site resources, tracking of time cost and quality,

and overall site activities. The procedure of placing orders for material needed on site is one of the examples of project controls procedures that reflects how project controls capability is being used within a firm. Those capabilities can be evaluated through different measures. The first is the availability of such procedures and tools in the firm, and how long such procedures have been used in previous projects along with analyzing the previous experience with these procedures. The reporting system and the cost control procedures can also give an indication on how the firm is capable controlling the project. Moreover, tracking record of quality of job (length of punch list), schedule and cost procedures can also be a measure of how effective the available project control procedures are. Furthermore, communication and documentation are important criteria to be considered when evaluating the firm's management capabilities. The degree of how good communication and documentation are will reveal how much the firm is organized internally and with all external stakeholders. Surely, if a firm has a good internal and external communication, it will have less misunderstanding and abortive work on site. Moreover, if such communication is well- documented, the contractor shall have minor issues in managing the stakeholders in any project. Using a software for all communication and documentation, together with clear and user-friendly forms, can be considered as measures that should be looked into while checking this criterion. A construction firm without proper risk management capabilities will result in various problems in the execution of the project since it indicates lack of proper preparation, and hence it will result in a negative impact on all project's parties and project's success. Risk management strategy will give the firm the general outline on how to act upon having a critical issue on site. It will consider all possible risks that can be encountered with the project and try to omit, transfer or mitigate those risks. The availability of a strategy and the tools and procedures used to forecast risks, together with providing examples of risk mitigation or elimination in previous projects (risk that would affect cost and time) are some of the indicators that should be examined in evaluating the risk management strategy. A construction firm without proper risk management capabilities will result in various problems in the execution of the project since it indicates lack of proper preparation, and hence it will result in a negative impact on all project's parties and project's success. Risk management strategy will give the firm the general outline on how to act upon having a critical issue on site. Table 3.3 represents the criteria that fall in the "contractors' characteristics" group 3 along with their definitions and citations.

Table 3. 3 Group 3 – Contractors' Characteristics Identification

	Criteria	Definition	Citation	Frequency
Group 3	Project Management Capability	Investigate the abilities of the firm to handle, manage and execute the project with high standard of project management techniques and tools	[13] [15] [17] [38] [40] [42]	6
	Number and Qualifications of key Personnel	Evaluate the staff qualification of the company which will give a good indicator on how the company is going to manage the project. The more qualified the staff of the company are, the better ability to project manage and resolve issues on site.	[13] [17] [38] [18] [41] [42]	6
	Project Controls Capability	Evaluate the procedures and tools that the company uses to have a full control on site resources, tracking of time cost and quality, and overall site activities	[13] [41] [42]	3
	Communication and Documentation	Evaluates how good the Communication and Documentation that the firm have and indicates how much the firm is organized internally and manage all external stakeholders	[13] [41]	2
	Risk Management Capability	Measures the firm the general outline on how to act upon having a critical issue on site.	[17]	1

3.5 Group 4- Sustainability and Technology Practices

Due to the nature of the construction industry, firms should cope with the latest sustainability and technology practices available in the market. Sustainability and technology practices will surely enhance workmanship and productivity and reduce cost. This will definitely increase the chances of project success. Moreover, this criterion reflects how the company acts towards its social responsibility and what measures the company takes to enhance the lifestyle of the entire community rather than just complete one single project . The four sub-criteria used to examine the firm's sustainability and technology practices are: use of sustainable construction practices, social impact (Corporate Social Responsibility CSR), image and reputation and use of technology. Sustainable construction practices use materials and resources in construction that have continuous supplies and multiple sources. The number of key personal within the firm that are LEED certified can reflect the firm's commitment towards shifting to Sustainable Construction Practices. Furthermore, the number of completed green projects (example: with high recyclable waste percentage) can be used as a factor for evaluating if the contractor is keen to implement sustainable construction

practices. Social impact is another dimension that should be considered while assessing companies. Construction companies should not only focus on generating profit, but they should also make sure that their work practices have a positive impact on the society. A review of the firm's corporate social responsibility (CSR) practices can also give a good indication on how the company is keen to serve the entire community. Construction companies usually rely on their image and reputation within the market to get new projects or at least get invited to a tender process. High number of disputes with clients, poor workmanship, failing to follow the construction program, and fatal incidents are some of the factors that create a negative impact on the contractor reputation. Likewise, with sustainability, the use of technology in construction will surely increase the chances of project success, improve workmanship, productivity and reduce cost. new material, new application methods, new machinery and the use of the latest softwares are some of the aspects that should be examined while evaluating this sub-criterion. Table 3.4 represents the criteria that fall in the group 4 "contractors' characteristics" along with their definitions and citations.

Table 3.4 Group 4 - Contractors' Characteristics Identification

	Criteria	Definition	Citation	Frequency
Group 4	Sustainability and Technology Practices	Ensures that firm is coping with the market new technologies which enhance workmanship, productivity, reduce cost and eventually increase chances of project success. Moreover, this group reflects how the company act towards its social responsibility and what measures the company is taking to enhance the lifestyle of the entire community rather than just complete one single project.	[43]	1
	Use of Sustainable Construction Practices	How frequent the firm uses materials and resources in construction that have continuous supplies and multiple sources.	Based on field experience	N/A
	Social Impact (Corporate and Social Responsibility CSR)	Indicates how the company is keen to serve the entire community rather than focusing on the firm's profit only.	Based on field experience	N/A
	Image and Reputation	Indicates the mental picture that the market have towords the company	[12] [13] [17] [18] [38] [43]	6
	Use of Technology (e.g. BIM)	Review how frequent the firm uses the latest market Technologies in construction and how it is affecting the project success.	[43]	1

Chapter 4. Results and Analysis

4.1 Respondent Profile

The survey was administered to 45 professional personnel from different disciplines and of different roles within the industry. The 45 surveys were administered to subjects assuming 3 main roles: consultants, contactors and clients with 15 representatives from each discipline. The respondents varied in their years of experience, the projects types that they have worked on, and the average sizes of the projects completed in terms of money. The respondents belonged to local and international firms that work in the UAE construction industry. Table 4.1 summarizes the respondent profile.

Table 4.1 Respondent profile Summary

Number of Respondents		45
Years of Experience	**No.**	**%**
<10 years	20	44.4%
11-20 years	9	20.0%
> 20 years	16	35.6%
Project Types	**No.**	**%**
Housing	4	8.9%
Building	24	53.3%
Industrial	1	2.2%
Infrastructure	16	35.6%
Average Project Size (US$)	**No.**	**%**
<50 M	8	17.8%
50-100M	16	35.6%
>100M	21	46.7%
Local Vs International	**No.**	**%**
Local	30	77.8%
International	15	33.3%
Role	**No.**	**%**
Owner	15	33.3%
Contractor	15	33.3%
Engineering Consultant	15	33.3%

4.2 Effect on Cost Success of the Projects

The results ranked the 4 categories with respect to their effect on cost success of the projects as follows: project management capabilities (0.416), past experience and past performance (0.269), sustainability and technology practices (0.168) and firm's capacity (0.146).

Locally, within the groups, the characteristics were ranked as follows: in project management capabilities group, the project controls capability (0.303) was ranked as the most important characteristic within the group followed by number and qualifications of key personnel (0.248), communication and documentation (0.226) and risk management capability (0.224). Figure 4.1 reflects the effect of characteristics within the project management capabilities group on project's cost success.

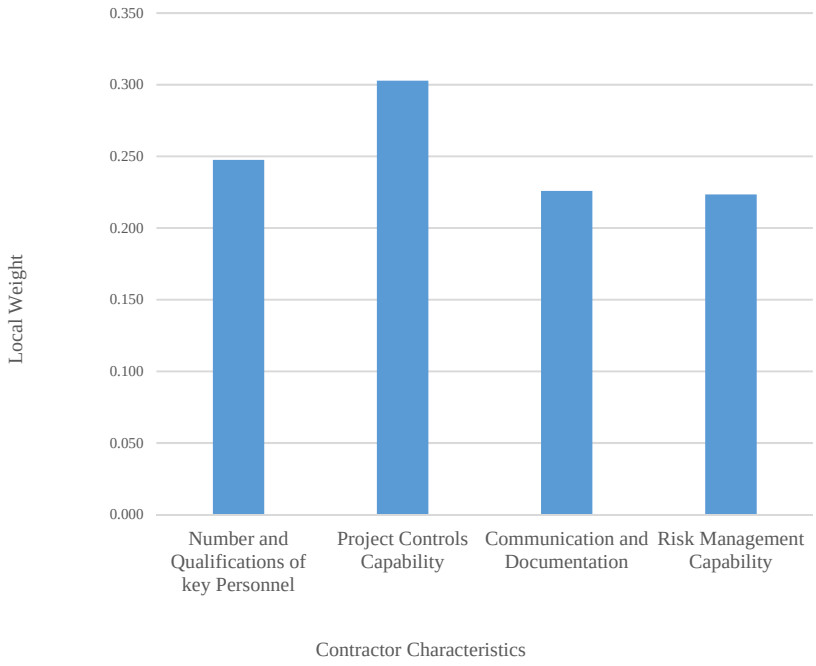

Figure 4.1 Project management capabilities – Effect on cost

For past experience and past performance group, the highest ratio went to the company past performance (time and cost) (0.327). The second characteristic was found to be past quality performance (0.327) followed by number and scale of completed projects (0.171) and past safety performance (0.156). Figure 4.2 shows the effects of the characteristics within past experience and past performance group on project's cost success

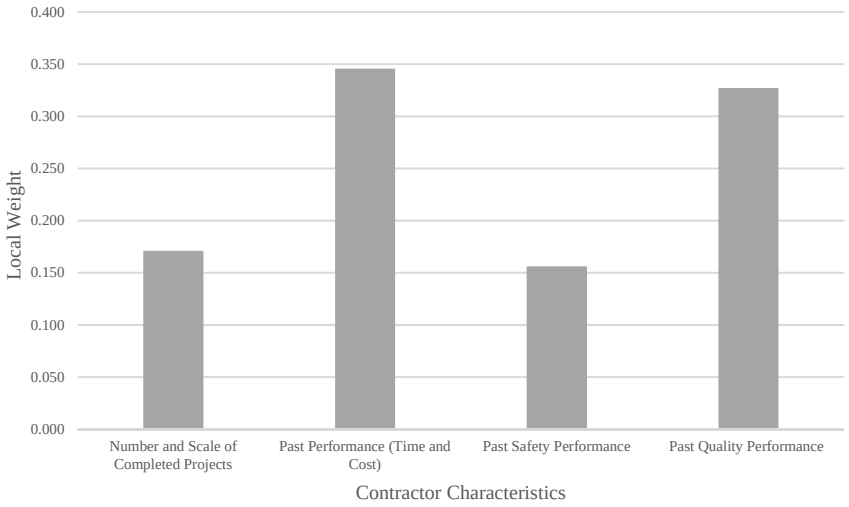

Figure 4.2 Past experience and past performance – Effect on cost

The characteristics within sustainability and technology practices group had the following ranking: both the use of sustainable construction practices and use of technology had the highest effect (0.327) followed by image and reputation (0.179) and social impact (0.167) had the least effect. Figure 4.3 displays the effects of the characteristics within the sustainability and technology practices group on Project's cost success

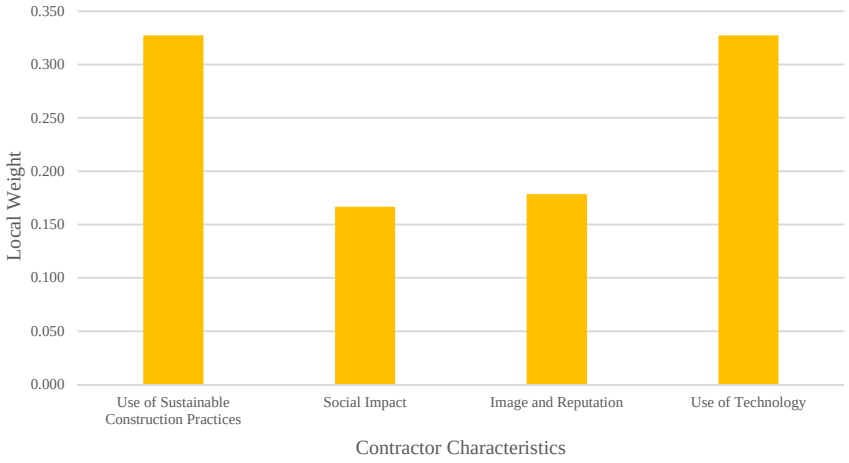

Figure 4.3 Sustainability and technology practices – Effect on cost

For the last group, firm's capacity, financial stability (0.363) was found to be the most effective characteristic on cost success followed by labor availability (0.247), equipment availability (0.233) and current workload (0.158). Figure 4.4 shows the effects of the characteristics within firm's capacity group on project's cost success.

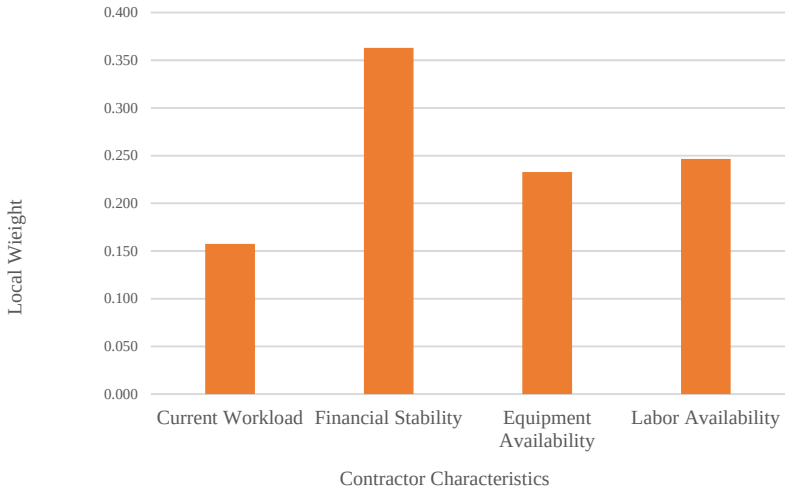

Figure 4.4 Firm's capacity – Effect on cost

When evaluating the sixteen characteristics together regardless of the group, the results from the software are as follows: project controls capability (0.126), number and qualifications of key personnel (0.103), communication and documentation (0.094), past performance (time and cost) (0.093), risk management capability (0.093), past quality performance (0.088), use of sustainable construction practices (0.055), use of technology (e.g. BIM) (0.055), financial stability (0.053), number and scale of completed projects (0.046), past safety performance (0.042), labor availability (0.036), equipment availability (0.034), image and reputation (0.030), social impact (Corporate Social Responsibility CSR) (0.028), current workload (0.023). Figure 4.5 represents the effects of the 16 contractor's characteristics on the cost success of the project. Table 4.2 summarizes the effects of contractors' characteristics on cost success of the projects.

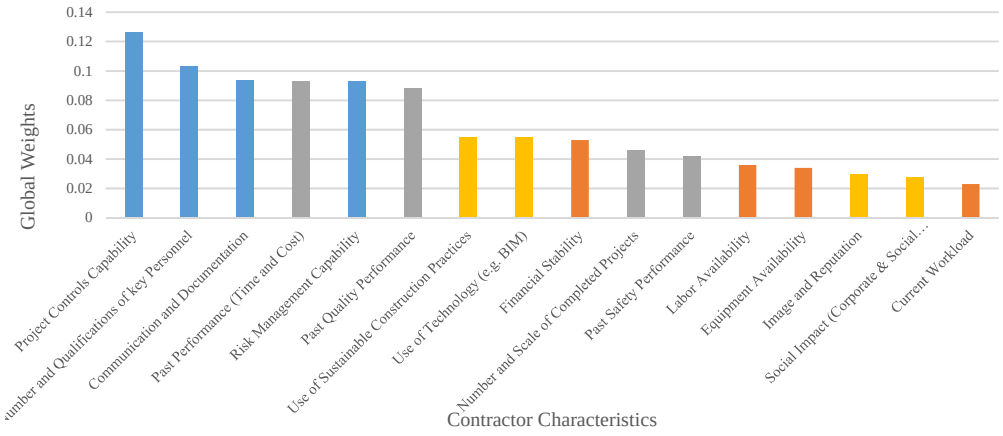

Figure 4.5 Effect of the 16 contractors' characteristics on the cost success

Table 4.2 Effect on cost success of the projects

Contractor Characteristics Ranking	Main Categories Ranking	Category	Contractor Characteristics	Local	Global
	4	Firm's Capacity			0.146
16			Current Workload	0.158	0.023
9			Financial Stability	0.363	0.053
13			Equipment Availability	0.233	0.034
12			Labor Availability	0.247	0.036
	2	Past Experience and Past Performance			0.269
10			Number and Scale of Completed Projects	0.171	0.046
4			Past Performance (Time and Cost)	0.346	0.093
11			Past Safety Performance	0.156	0.042
6			Past Quality Performance	0.327	0.088
	1	Project Management Capabilities			0.416
2			Number and Qualifications of key Personnel	0.248	0.103
1			Project Controls Capability	0.303	0.126
3			Communication and Documentation	0.226	0.094
5			Risk Management Capability	0.224	0.093
	3	Sustainability and Technology Practices			0.168
7			Use of Sustainable Construction Practices	0.327	0.055
15			Social Impact	0.167	0.028
14			Image and Reputation	0.179	0.03
8			Use of Technology	0.327	0.055

The five most effective characteristics that affect projects' cost are project controls capability, number and qualifications of key personnel, communication and documentation, past performance and risk management capability. Four of the top five characteristics are found to be from the project management capabilities group. This shows that project management plays a significant role, not only on project cost but also on overall success of the project. Project controls capability, number and qualifications of key personnel, communication and documentation and risk management capability show the internal strength and amount of control that organizations have. Moreover, the results show that the way that the company is organized internally has a direct effect on the projects' cost regardless of the firm's capacity. Firm capacity characteristics have less effect than all other groups. Financial

strength and availability of labor and equipment will have minimum effect if those resources are not managed properly.

4.3 Effect on Time Success of the Projects

Considering the effect on the "time factor" of the project, the groups are ranked on the four categories as follows: project management capabilities (0.403), past experience and past performance (0.259), sustainability and technology practices (0.173) and firm's capacity (0.166).

Locally, within the four groups, the characteristics are ranked as follows: in project management capabilities group, the project controls capability (0.333) is ranked as the most important characteristic within the group, followed by number and qualifications of key personnel (0.285), risk management capability (0.199) and communication and documentation (0.184) respectively. Figure 4.6 shows the effect of the characteristics within the project management capabilities group on project's time success.

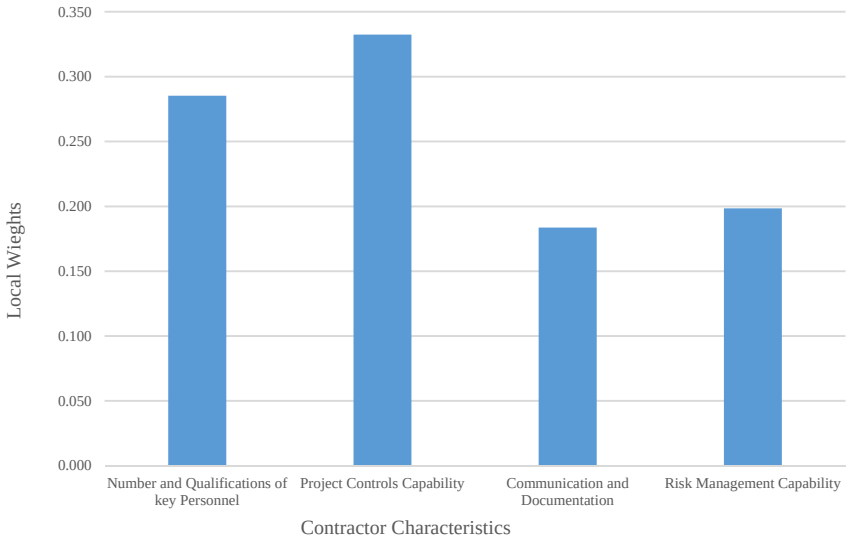

Figure 4.6 Project management capabilities – Effect on time

For past experience and past performance group, the highest weight went to the company past performance (time and cost) (0.344). The second characteristic is past quality performance (0.259), followed by number and scale of completed projects (0.232) and past safety performance (0.166). Figure 4.7 shows the effect of the characteristics within past experience and past performance group on project's time success.

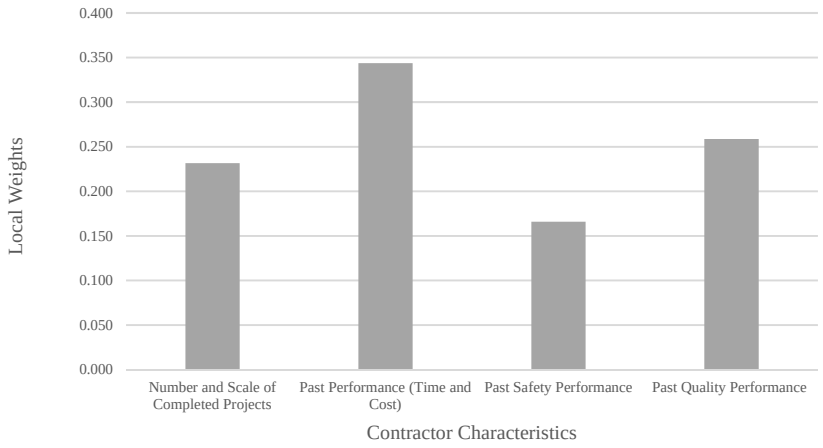

Figure 4.7 Past experience and past performance – Effect on time

The characteristics within sustainability and technology practices group had the following ranking: use of technology had the highest effect (0.329), followed by use of sustainable construction practices (0.324), social impact (0.179), image and reputation (0.168) with the least effect within this group. Figure 4.8 shows the effects of the characteristics within the sustainability and technology practices group on project's time success.

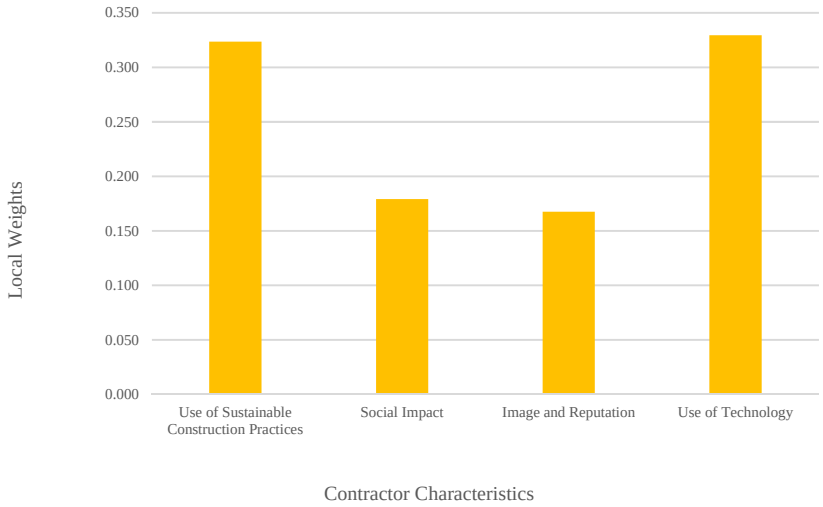

Figure 4.8 Sustainability and technology practices – Effect on time

For the last group, firm's capacity, financial stability (0.363) is found to be the most effective characteristic, followed by labor availability (0.247), equipment availability (0.233) and current workload (0.158). Figure 4.9 shows the effects of the characteristics within the firm's capacity group on project's time success.

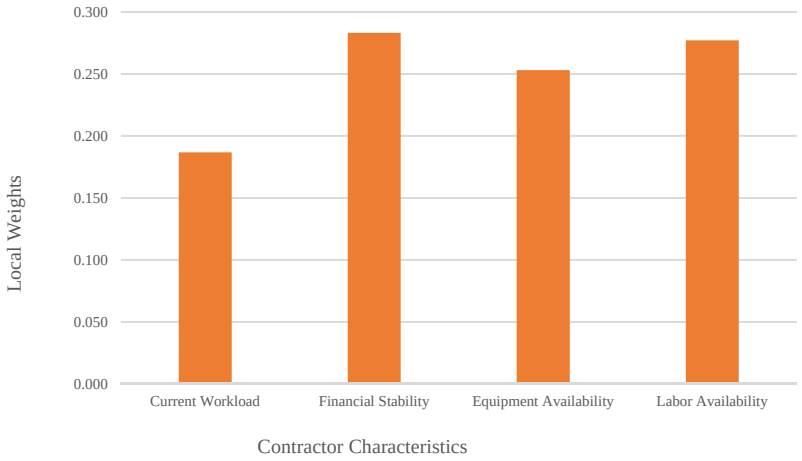

Figure 4.9 Firm's capacity – Effect on time

When evaluating the sixteen characteristics together against the time success factor regardless of the group, the results from the software were as follows: project controls capability (0.134), number and qualifications of key personnel (0.115), past performance (time and cost) (0.089), risk management capability (0.080), communication and documentation (0.074), past quality performance (0.067), number and scale of completed projects (0.060), use of technology (e.g. BIM) (0.057), use of sustainable construction practices (0.056), financial stability (0.047), labor availability (0.046), past safety performance (0.043), equipment availability (0.042), current workload (0.031), social impact (Corporate Social Responsibility CSR) (0.031), and image and reputation (0.029). Figure 4.10 represents the effect of the sixteen contractor characteristics on the time success of the project

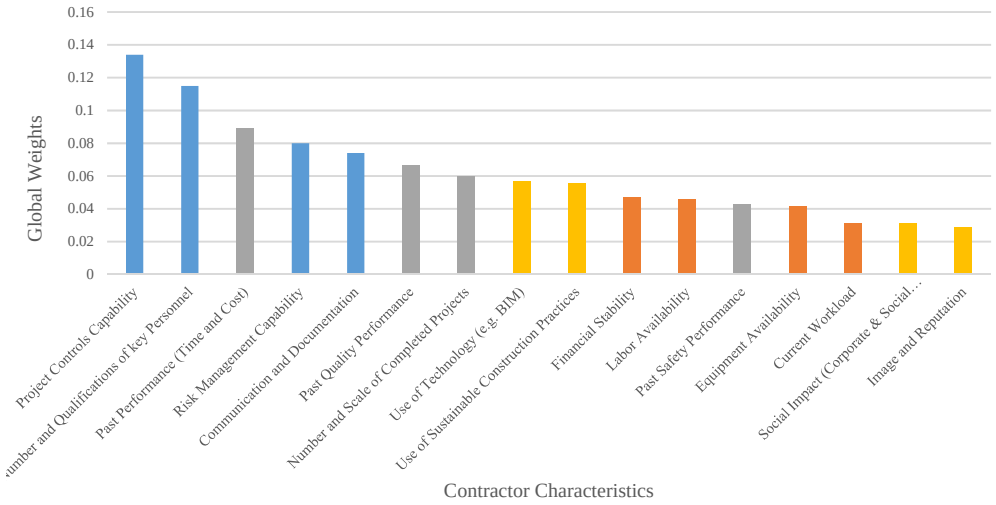

Figure 4.10 Effects of the 16 contractor's characteristics on the time success

Table 4.3 summarizes the effect of contractors' characteristics on time success of the projects.

Table 4.3 Results Summary - contractor's' characteristics – Effect on time

Contractor Characteristics Ranking	Main Categories Ranking	Category	Contractor Characteristics	Local	Global
	4	Firm's Capacity			0.166
14			Current Workload	0.187	0.031
10			Financial Stability	0.283	0.047
13			Equipment Availability	0.253	0.042
11			Labor Availability	0.277	0.046
	2	Past Experience and Past Performance			0.259
7			Number and Scale of Completed Projects	0.232	0.06
3			Past Performance (Time and Cost)	0.344	0.089
12			Past Safety Performance	0.166	0.043
6			Past Quality Performance	0.259	0.067
	1	Project Management Capabilities			0.403
2			Number and Qualifications of key Personnel	0.285	0.115
1			Project Controls Capability	0.333	0.134
5			Communication and Documentation	0.184	0.074
4			Risk Management Capability	0.199	0.08
	3	Sustainability and Technology Practices			0.173
9			Use of Sustainable Construction Practices	0.324	0.056
15			Social Impact	0.179	0.031
16			Image and Reputation	0.168	0.029
8			Use of Technology	0.329	0.057

The five most effective characteristics that effects projects' time were found similar to those effecting cost success with slight difference in the ranking. The sequence was as follows: project controls capability, number and qualifications of key personnel, past performance, risk management capability, and communication and documentation.

4.4 Effect on Quality Success of the Projects

Regarding the success in the quality aspect of the project, the four categories are ranked in the following order: project management capabilities (0.396), past experience and past performance (0.236), sustainability and technology practices (0.202) and firm's capacity (0.164).

When evaluating the characteristics within each of the group, the characteristics were ranked as follows: In project management capabilities group, the project controls capability (0.361) was ranked as the most important characteristic within the group, followed by number and qualifications of key personnel (0.275), communication and documentation (0.189) and risk management capability (0.179). Figure 4.11 represents the effect of the characteristics within the project management capabilities group on project's quality success

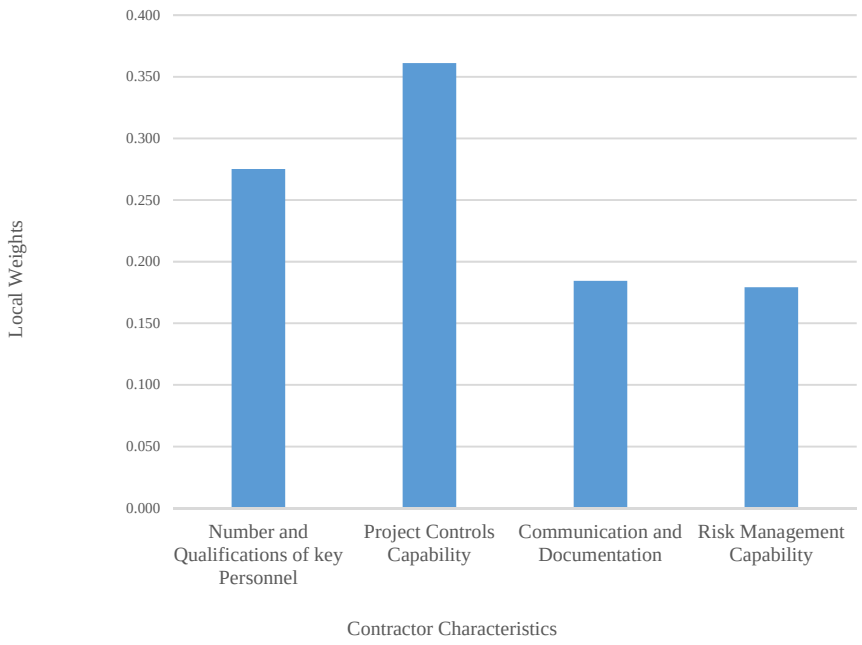

Figure 4.11 Project management capabilities – Effect on quality

For past experience and past performance group, the highest ratio went to the company past performance (time and cost) (0.327). The second characteristic was found to be past quality performance (0.327) followed by number and scale of completed projects (0.171) and past safety performance (0.156). Figure 4.12 shows the effects of the characteristics within the past experience and past performance group on project's quality success.

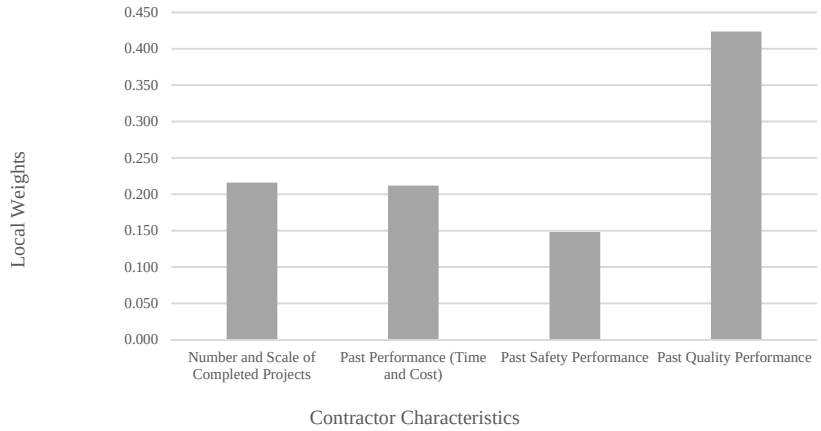

Figure 4.12 Past experience and past performance – Effect on quality

The characteristics within sustainability and technology practices group had the following ranking: use of technology had the highest effect (0.297) followed by use of

sustainable construction practices (0.282), image and reputation (0.257) and social impact (0.163) had the least effect. Figure 4.13 shows the effects of the characteristics within the sustainability and technology practices group on project's quality success.

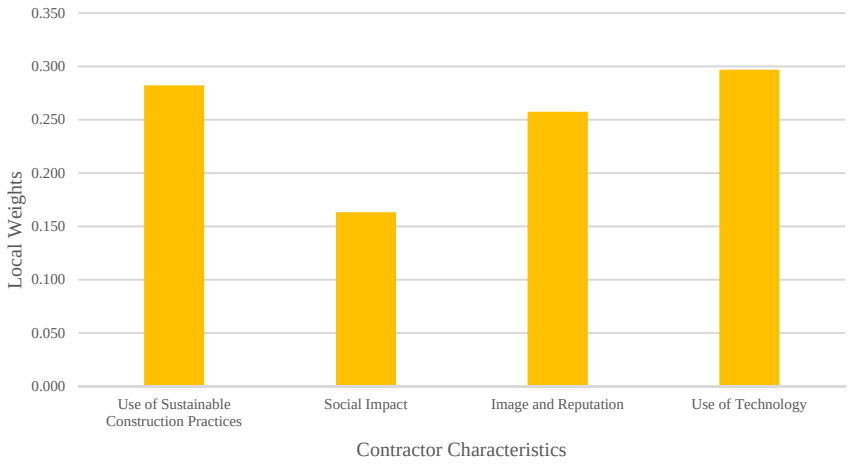

Figure 4.13 Sustainability and technology practices – Effect on quality

For the last group, firm's capacity, labor availability (0.247) was found to be the most effective characteristic, followed by equipment availability (0.250), current workload (0.244) and financial stability (0.207). Figure 4.14 shows the effects of firm's capacity group on projects quality success.

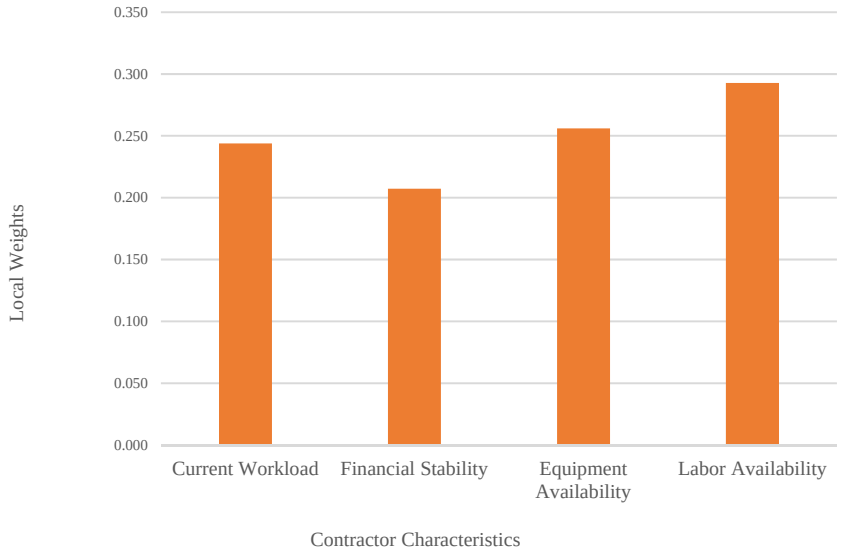

Figure 4.14 Firm's capacity- Effect on quality

When evaluating the sixteen characteristics together regardless of the group, the results are as follows: project controls capability (0.143), number and qualifications of key personnel (.109), past quality performance (0.1), communication and documentation (0.073), risk management capability (0.071), use of technology (0.060), use of sustainable construction practices (0.057), image and reputation (0.052), number and scale of completed projects (0.051), performance (time and cost) (0.050), labor availability (0.048), equipment availability (0.042), current workload (0.040), past safety performance (0.035), financial stability (0.034), and social impact (Corporate Social Responsibility CSR) (0.033). Figure 4.15 shows the effect of characteristics within sustainability and technology practices group on project's quality success. Figure 4.15 reflects the effects of the characteristics within the sustainability and technology practices group on project's quality success.

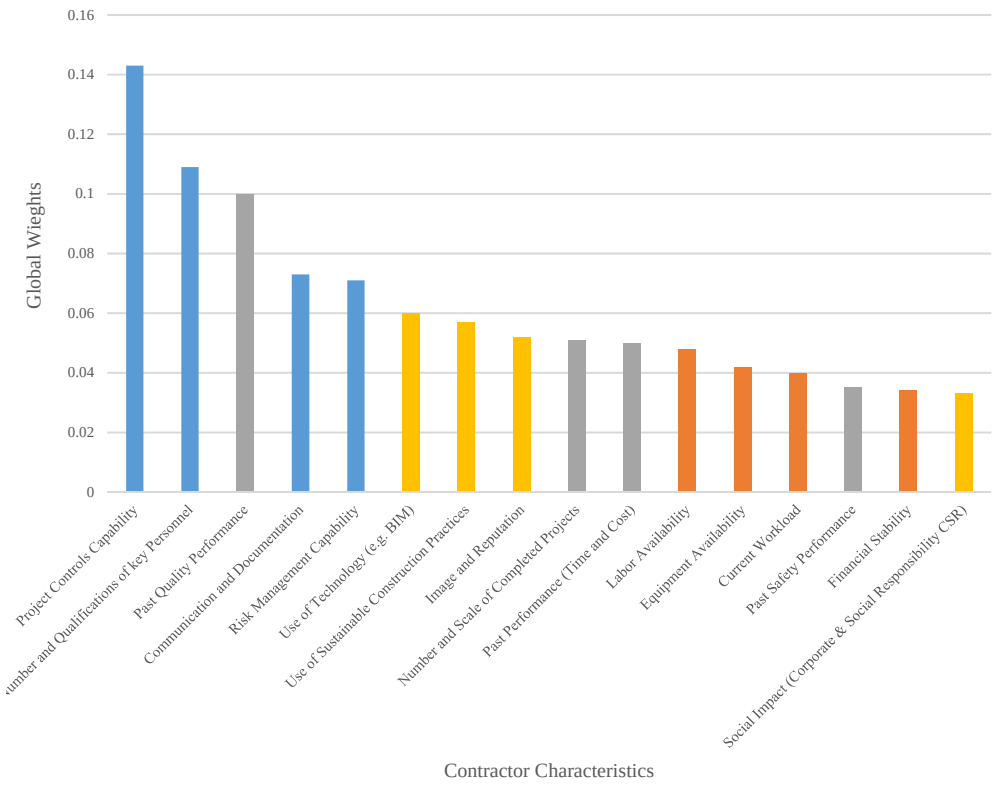

Figure 4.15 shows the effect of the 16 contractor characteristics on the quality success

Table 4.4 below summarizes the effect of contractors' characteristics on quality success of the projects:

Table 4.4: Survey Results Summary of the the effect of contractors' characteristics on quality success of the projects

Contractor Characteristics Ranking	Main Categories Ranking	Category	Contractor Characteristics	Local	Global
	4	Firm's Capacity			0.164
14			Current Workload	0.244	0.04
10			Financial Stability	0.207	0.034
13			Equipment Availability	0.256	0.042
11			Labor Availability	0.293	0.048
	2	Past Experience and Past Performance			0.236
7			Number and Scale of Completed Projects	0.216	0.051
3			Past Performance (Time and Cost)	0.212	0.05
12			Past Safety Performance	0.148	0.035
6			Past Quality Performance	0.424	0.1
	1	Project Management Capabilities			0.396
2			Number and Qualifications of key Personnel	0.275	0.109
1			Project Controls Capability	0.361	0.143
5			Communication and Documentation	0.184	0.073
4			Risk Management Capability	0.179	0.071
	3	Sustainability and Technology Practices			0.202
9			Use of Sustainable Construction Practices	0.282	0.057
15			Social Impact	0.163	0.033
16			Image and Reputation	0.257	0.052
8			Use of Technology	0.297	0.06

4.5 Discussion of Results

The results of the survey on the contractor characteristics that affect the quality success of a project emphasized the importance of the project management capabilities of the contractor. Similar to cost and time, 4 of the top 5 characteristics were found to be from the project management capabilities group. Project controls capability, number and qualifications of key personnel, past quality performance, communication and documentation and risk management capability were ranked by the surveyor respectively. Past quality performance was the new contractor criterion that was introduced to the top 5 characteristics that affect the quality success replacing past performance (Cost and Time).

All success factors shared the same ranking of the main categories as follows: project management capabilities, past experience and past performance, sustainability and technology practices and firm's capacity. In previous related literature, however, past performance and experience was found to be the highest group, followed by project management capabilities, firm's capacity and sustainability and technology practices. This is probably due to the uniqueness of the construction industry in the UAE. The

complexity and number of projects that the contractor is involved in reflect the importance of the project management capabilities. Firm's capacity and the past experience and performance are not expected to be that affective without the availability and proper utilization of the the necessary project management capabilities. The same applies to sustainability and technology practices; in order to work well, the company needs to be well organized (excellent project management capabilities) in order to provide a fruitful outcome.

4.6 Comparing Financial Factors to Non-Financial Factors

The results of the survey showed that the bid price (financial) got 0.513, while the importance of evaluating the contractor characteristics were found to be (0.487). Those results are in accord with previous work found in literature on the importance of evaluating the non-financial factor in addition to the bid price (financial) [13] [14] [17] [18] [44]. This also reflects how mature the construction industry is in UAE, and it reflects the necessity to evaluate non-financial factors along with financial ones. Figure 4.16 reflects the prioritization percentage of financial and nonfinancial factors.

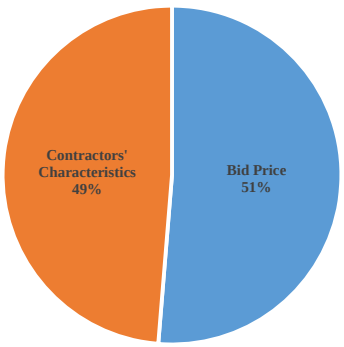

Figure 4.16 Prioritization of Financial Factors and Non-Financial Factors

4.7 Project Success Priority

The results obtained from the collected surveys ranked project success priority factors in the following order: quality (0.413), cost (0.317), and time (0.270). This is mainly dependent on the personal experience that the surveyors have gained during their career life. Definitely, the project success priority will vary from project to another. This data might help if the project success priority is not defined clearly from the contractor. Figure 4.17 represents the Project Success Priority

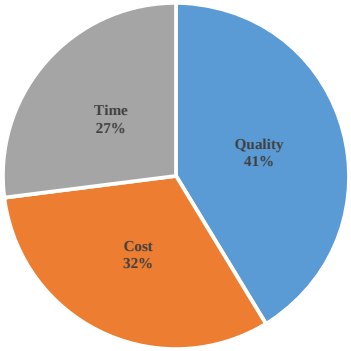

Figure 4.17 Project Success Priority

Chapter 5. The Forecasting Model

5.1 Overview

Using the results and data analysis from Chapter 4, the forecasting model is designed to gather the information necessary for predicting the final project outcomes. This model also helps in increasing the probability of project success as it links the non-financial contractor's characteristics to the project's success criteria. For practicality reasons, the model includes the bid price criteria as a financial factor. The combination of financial and non-financial factors makes the model more comprehensive and gives the evaluator the ability to have a full analysis of the contractors at one stop, which will result in selecting the best fit contractor for the given project.

5.2 The Model

Equation (1) is used to calculate the Success Score of Bidder *i* (*SS_i*). *SS_i* of all bidder should be compared in order to select the best fit contractor based on both financial and non-financial factors.

$$SS_i = C_F \cdot S_{Fi} + C_{NF} \cdot S_{NFi} \quad (1)$$

where,

SS_i = Success score of bidder *i*

i = 1 to n (n- number of bidders)

C_f = Importance of considering financial factors (survey results = 0.513)

S_{F1} = Score of bidder *i* with respect to financial factors

C_{NF} = Importance of considering non-financial factors (survey results = 0.487)

S_{NFi} = Score of bidder *i* with respect to non-financial factors

Using Survey Results, Equation 1 will be as follows:

$$SS_i = 0.513 \cdot S_{Fi} + 0.487 \cdot S_{NFi}$$

Equation (2) is used to calculate Score of bidder *i* with respect to non-financial factors (*S_{NFi}*).

$$S_{NFi} = S_{Ci} + S_{Ti} + S_{Qi} \quad (2)$$

where,

S_{Ci} = Score of bidder *i* in terms of cost success

S_{Ti} = Score of bidder *i* in terms of time success

S_{Qi} = Score of bidder *i* in terms of quality success

Equation (3) is used to calculate the score of bidder *i* in terms of cost success (S_{Ci})

$$S_{Ci} = P_C \cdot (S_{CiG1} + S_{CiG2} + S_{CiG3} + S_{CiG4}) \quad (3)$$

where,

S_{Ci} = Score of bidder *i* with respect to cost success

P_c = Priority of cost success (survey results = 0.317)

S_{CiG1}= Score of bidder *i* with respect to group 1 criteria when cost success is evaluated

S_{CiG2}= Score of bidder *i* with respect to group 2 criteria when cost success is evaluated

S_{CiG3}= Score of bidder *i* with respect to group 3 criteria when cost success is evaluated

S_{CiG4}= Score of bidder *i* with respect to group 4 criteria when cost success is evaluated

Equation (4) is used to calculate the Score of bidder *i* with respect to group 1 criteria when cost success is evaluated (S_{CiG1})

$$S_{CiG1} = \sum_{j=1}^{4} E_{j-C} \cdot S_{ij} \quad (4)$$
$$= E_{1-C} \cdot S_{i1} + E_{2-C} \cdot S_{i2} + E_{3-C} \cdot S_{i3} + E_{4-C} \cdot S_{i4}$$

where,

$E_{j\text{-}c}$ = Effect of criteria *j* on cost success

S_{ij} = Score of bidder *i* in criteria *j* from 1 to 10 (1 poor – 10 perfect)

$E_{1\text{-}c}$ = Effect of current workload criteria on cost success (survey results = 0.023)

S_{i1} = Score of bidder *i* in current workload criteria - from 1 to 10

$E_{2\text{-}c}$ = Effect of financial stability criteria on cost success (survey results = 0.053)

S_{i2} = Score of bidder *i* in financial stability criteria - from 1 to 10

$E_{3\text{-}c}$ = Effect of equipment availability criteria on cost success (survey results 0.034)

S_{i3} = Score of bidder *i* in equipment availability criteria - from 1 to 10

$E_{4\text{-}c}$ = Effect of labor availability criteria on cost success (survey results = 0.036)

S_{i4} = Score of bidder *i* in labor availability criteria - from 1 to 10

Using survey results, Equation (4) will be as follows:

$$S_{CiG1} = \sum_{j=1}^{4} \mathrm{E_{j-C}} \cdot S_{ij}$$

$$= \mathrm{E_{1-C}} \cdot S_{i1} + \mathrm{E_{2-C}} \cdot S_{i2} + \mathrm{E_{3-C}} \cdot S_{i3} + \mathrm{E_{4-C}} \cdot S_{i4}$$

$$= 0.023 \cdot S_{i1} + 0.053 \cdot S_{i2} + 0.034 \cdot S_{i3} + 0.036 \cdot S_{i4}$$

Equation (5) is used to calculate the score of bidder *i* with respect to group 2 criteria when cost success is evaluated (S_{CiG2})

$$S_{CiG2} = \sum_{j=5}^{8} \mathrm{E_{j-C}} \cdot S_{ij} \quad (5)$$

$$= \mathrm{E_{5-C}} \cdot S_{i5} + \mathrm{E_{6-C}} \cdot S_{i6} + \mathrm{E_{7-C}} \cdot S_{i7} + \mathrm{E_{8-C}} \cdot S_{i8}$$

where,

$E_{5\text{-}C}$ = Effect of number and scale of completed projects criteria on cost success (survey results = 0.046)

S_{i5} = Score of bidder *i* in number and scale of completed projects criteria - from 1 to 10

$E_{6\text{-}C}$ = Effect of past performance (time and cost) criteria on cost success (survey results = 0.093)

S_{i6} = Score of bidder *i* in past performance (time and cost) criteria - from 1 to 10

$E_{7\text{-}c}$ = Effect of past safety performance criteria on cost success (survey results = 0.042)

S_{i7} = Score of bidder *i* in past safety performance criteria - from 1 to 10

$E_{8\text{-}c}$ = Effect of Past Quality Performance criteria on Cost Success (Survey Results = 0.088)

S_{i8} = Score of bidder *i* in past quality performance criteria - from 1 to 10

Using survey results, Equation (5) will be as follows:

$$S_{CiG2} = \sum_{j=5}^{8} \mathrm{E_{j-C}} \cdot S_{ij}$$

$$= \mathrm{E}_{5-\mathrm{C}} \cdot S_{i5} + \mathrm{E}_{6-\mathrm{C}} \cdot S_{i6} + \mathrm{E}_{7-\mathrm{C}} \cdot S_{i7} + \mathrm{E}_{8-\mathrm{C}} \cdot S_{i8}$$

$$= 0.046 \cdot S_{i5} + 0.093 \cdot S_{i6} + 0.042 \cdot S_{i7} + 0.088 \cdot S_{i8}$$

Equation (6) is used to calculate the Score of bidder *i* with respect to group 3 criteria when cost success is evaluated (S_{CiG3})

$$S_{CiG3} = \sum_{j=9}^{12} \mathrm{E}_{\mathrm{j}-\mathrm{C}} \cdot S_{ij} \qquad (6)$$

$$= \mathrm{E}_{9-\mathrm{C}} \cdot S_{i9} + \mathrm{E}_{10-\mathrm{C}} \cdot S_{i10} + \mathrm{E}_{11-\mathrm{C}} \cdot S_{i11} + \mathrm{E}_{12-\mathrm{C}} \cdot S_{i12}$$

where,

$E_{9\text{-}C}$ = Effect of number and qualifications of key personnel criteria on cost success (survey results = 0.103)

S_{i9} = Score of bidder *i* in number and qualifications of key personnel criteria - from 1 to 10

$E_{10\text{-}C}$ = Effect of project controls capability criteria on cost success (survey results = 0.126)

S_{i10} = Score of bidder *i* in project controls capability criteria - from 1 to 10

$E_{11\text{-}C}$ = Effect of communication and documentation criteria on cost success (survey results = 0.094)

S_{i11} = Score of bidder *i* in communication and documentation criteria - from 1 to 10

$E_{12\text{-}C}$ = Effect of risk management capability criteria on cost success (survey results = 0.093)

S_{i12} = Score of bidder *i* in risk management capability criteria - from 1 to 10

Using survey results, Equation (6) will be as follows:

$$S_{CiG3} = \sum_{j=9}^{12} \mathrm{E}_{\mathrm{j}-\mathrm{C}} \cdot S_{ij}$$

$$= \mathrm{E}_{9-\mathrm{C}} \cdot S_{i9} + \mathrm{E}_{10-\mathrm{C}} \cdot S_{i10} + \mathrm{E}_{11-\mathrm{C}} \cdot S_{i11} + \mathrm{E}_{12-\mathrm{C}} \cdot S_{i12}$$

$$= 0.046 \cdot S_{i9} + 0.093 \cdot S_{i10} + 0.042 \cdot S_{i11} + 0.088 \cdot S_{i12}$$

Equation (7) is used to calculate the Score of bidder *i* with respect to group 4 criteria when cost success is evaluated (S_{CiG4})

$$S_{CiG4} = \sum_{j=13}^{16} \mathrm{E}_{\mathrm{j}-\mathrm{C}} \cdot S_{ij} \qquad (7)$$

$$= \mathrm{E}_{13-\mathrm{C}} \cdot S_{i13} + \mathrm{E}_{14-\mathrm{C}} \cdot S_{i14} + \mathrm{E}_{15-\mathrm{C}} \cdot S_{i15} + \mathrm{E}_{16-\mathrm{C}} \cdot S_{i16}$$

where,

$E_{13\text{-}c}$ = Effect of use of sustainable construction practices criteria on cost success (survey results = 0.055)

S_{i13} = Score of bidder *i* in use of sustainable construction practices criteria - from 1 to 10

$E_{14\text{-}c}$ = Effect of social impact (Corporate and Social Responsibility CSR) criteria on cost success (survey results = 0.028)

S_{i14} = Score of bidder *i* in social impact (Corporate and Social Responsibility CSR) criteria - from 1 to 10

$E_{15\text{-}c}$ = Effect of image and reputation criteria on cost success (survey results = 0.03)

S_{i15} = Score of bidder *i* in image and reputation criteria - from 1 to 10

$E_{16\text{-}c}$ = Effect of use of technology criteria on cost success (survey results = 0.055)

S_{i16} = Score of bidder *i* in use of technology criteria - from 1 to 10

Using survey results, Equation (7) will be as follows:

$$S_{CiG4} = \sum_{j=13}^{16} E_{j-C} \cdot S_{ij}$$

$$= E_{13-C} \cdot S_{i13} + E_{14-C} \cdot S_{i14} + E_{15-C} \cdot S_{i15} + E_{16-C} \cdot S_{i16}$$

$$= 0.055 \cdot S_{i13} + 0.028 \cdot S_{i14} + 0.03 \cdot S_{i15} + 0.055 \cdot S_{i16}$$

Equation (8) is used to calculate the score of bidder *i* in terms of time success (S_{Ti})

$$S_{Ti} = P_T \cdot (S_{TiG1} + S_{TiG2} + S_{TiG3} + S_{TiG4}) \quad (8)$$

where,

S_{TI} = Score of bidder *i* with respect to time success

P_T = Priority of cost success (survey results = 0.27)

S_{TiG1}= Score of bidder *i* with respect to group 1 criteria when time success is evaluated

S_{TiG2}= Score of bidder *i* with respect to group 2 criteria when time success is evaluated

S_{TiG3}= Score of bidder *i* with respect to group 3 criteria when time success is evaluated

S_{TiG4}= Score of bidder *i* with respect to group 4 criteria when time success is evaluated

Equation (9) is used to calculate the score of bidder *i* with respect to group 1 criteria when time success is evaluated (S_{TiG1})

$$S_{TiG1} = \sum_{j=1}^{4} E_{j-T} \cdot S_{ij} \quad (9)$$
$$= E_{1-T} \cdot S_{i1} + E_{2-T} \cdot S_{i2} + E_{3-T} \cdot S_{i3} + E_{4-T} \cdot S_{i4}$$

where,

$E_{j\text{-}T}$ = Effect of criteria *j* on time success

S_{ij} = Score of bidder *i* in criteria *j* from 1 to 10 (1 poor – 10 perfect)

$E_{1\text{-}T}$= Effect of current workload criteria on time success (survey results = 0.029)

S_{i1} = Score of bidder *i* in current workload criteria - from 1 to 10

$E_{2\text{-}T}$ = Effect of financial stability criteria on time success (survey results = 0.056)

S_{i2} = Score of bidder *i* in financial stability criteria - from 1 to 10

$E_{3\text{-}T}$= Effect of equipment availability criteria on time success (survey results = 0.042)

S_{i3} = Score of bidder *i* in equipment availability criteria - from 1 to 10

$E_{4\text{-}T}$= Effect of labor availability criteria on time success (survey results = 0.043)

S_{i4} = Score of bidder *i* in labor availability criteria - from 1 to 10

Using survey results, Equation (9) will be as follows:

$$S_{TiG1} = \sum_{j=1}^{4} E_{j-T} \cdot S_{ij}$$
$$= E_{1-T} \cdot S_{i1} + E_{2-T} \cdot S_{i2} + E_{3-T} \cdot S_{i3} + E_{4-T} \cdot S_{i4}$$
$$= 0.029 \cdot S_{i1} + 0.056 \cdot S_{i2} + 0.042 \cdot S_{i3} + 0.043 \cdot S_{i4}$$

Equation (10) is used to calculate the Score of contractor *i* with respect to Group 2 Criteria when Time success is evaluated (S_{TiG2})

$$S_{TiG2} = \sum_{j=5}^{8} E_{j-T} \cdot S_{ij} \quad (10)$$

$$= E_{5-T} \cdot S_{i5} + E_{6-T} \cdot S_{i6} + E_{7-T} \cdot S_{i7} + E_{8-T} \cdot S_{i8}$$

where,

$E_{5\text{-}T}$ = Effect of number and scale of completed projects criteria on time success (survey results = 0.047)

S_{i5} = Score of bidder *i* in number and scale of completed projects criteria - from 1 to 10

$E_{6\text{-}T}$ = Effect of past performance (time and cost) criteria on time success (survey results = 0.08)

S_{i6} = Score of bidder *i* in past performance (time and cost) criteria - from 1 to 10

$E_{7\text{-}T}$ = Effect of past safety performance criteria on time success (survey results = 0.046)

S_{i7} = Score of bidder *i* in past safety performance criteria - from 1 to 10

$E_{8\text{-}T}$= Effect of past quality performance criteria on time success (survey results = 0.067)

S_{i8} = Score of bidder *i* in past quality performance criteria - from 1 to 10

Using survey results, Equation (10) will be as follows:

$$S_{TiG2} = \sum_{j=5}^{8} E_{j-T} \cdot S_{ij}$$

$$= E_{5-T} \cdot S_{i5} + E_{6-T} \cdot S_{i6} + E_{7-T} \cdot S_{i7} + E_{8-T} \cdot S_{i8}$$

$$= 0.047 \cdot S_{i5} + 0.08 \cdot S_{i6} + 0.046 \cdot S_{i7} + 0.067 \cdot S_{i8}$$

Equation (11) is used to calculate the score of bidder *i* with respect to group 3 criteria when time success is evaluated (S_{TiG3})

$$S_{TiG3} = \sum_{j=9}^{12} E_{j-T} \cdot S_{ij} \qquad (11)$$

$$= E_{9-T} \cdot S_{i9} + E_{10-T} \cdot S_{i10} + E_{11-T} \cdot S_{i11} + E_{12-T} \cdot S_{i12}$$

where,

$E_{9\text{-}T}$ = Effect of number and qualifications of key personnel criteria on time success (survey results = 0.115)

S_{i9} = Score of bidder *i* in number and qualifications of key personnel criteria - from 1 to 10

$E_{10\text{-}T}$ = Effect of project controls capability criteria on time success (survey results = 0.134)

S_{i10} = Score of bidder *i* in project controls capability criteria - from 1 to 10

$E_{11\text{-}T}$ = Effect of communication and documentation criteria on time success (survey results = 0.089)

S_{i11} = Score of bidder *i* in communication and documentation criteria - from 1 to 10

$E_{12\text{-}T}$ = Effect of risk management capability criteria on time success (survey results = 0.074)

S_{i12} = Score of bidder *i* in risk management capability criteria - from 1 to 10

Using survey results, Equation (11) will be as follows:

$$S_{TiG3} = \sum_{j=9}^{12} \mathrm{E_{j-T}} \cdot S_{ij}$$

$$= \mathrm{E_{9-C}} \cdot S_{i9} + \mathrm{E_{10-C}} \cdot S_{i10} + \mathrm{E_{11-C}} \cdot S_{i11} + \mathrm{E_{12-C}} \cdot S_{i12}$$

$$= 0.115 \cdot S_{i9} + 0.134 \cdot S_{i10} + 0.089 \cdot S_{i11} + 0.074 \cdot S_{i12}$$

Equation (12) is used to calculate the score of bidder *i* with respect to group 4 criteria when time success is evaluated (S_{TiG4})

$$S_{TiG4} = \sum_{j=13}^{16} \mathrm{E_{j-T}} \cdot S_{ij} \qquad (12)$$

$$= \mathrm{E_{13-T}} \cdot S_{i13} + \mathrm{E_{14-T}} \cdot S_{i14} + \mathrm{E_{15-T}} \cdot S_{i15} + \mathrm{E_{16-T}} \cdot S_{i16}$$

where,

$E_{13\text{-}T}$ = Effect of use of sustainable construction practices criteria on time success (survey results = 0.06)

S_{i13} = Score of bidder *i* in use of sustainable construction practices criteria - from 1 to 10

$E_{14\text{-}T}$ = Effect of social impact (Corporate and Social Responsibility CSR) criteria on time success (survey results = 0.031)

S_{i14} = Score of bidder *i* in social impact (Corporate and Social Responsibility CSR) criteria - from 1 to 10

$E_{15\text{-}T}$ = Effect of image and reputation criteria on time success (survey results = 0.031)

S_{i15} = Score of bidder *i* in image and reputation criteria - from 1 to 10

$E_{16\text{-}T}$ = Effect of use of technology criteria on time success (survey results = 0.057)

S_{i16} = Score of bidder *i* in use of technology criteria - from 1 to 10

Using survey results, Equation (12) will be as follows:

$$S_{TiG4} = \sum_{j=13}^{16} \mathrm{E_{j-T}} \cdot S_{ij}$$

$$= \mathrm{E_{13-T}} \cdot S_{i13} + \mathrm{E_{14-T}} \cdot S_{i14} + \mathrm{E_{15-T}} \cdot S_{i15} + \mathrm{E_{16-T}} \cdot S_{i16}$$

$$= 0.06 \cdot S_{i13} + 0.031 \cdot S_{i14} + 0.031 \cdot S_{i15} + 0.057 \cdot S_{i16}$$

Equation 13 is used to calculate the score of bidder *i* in terms of quality success (S_{Qi})

$$S_{Qi} = \mathrm{P_Q} \cdot (S_{QiG1} + S_{QiG2} + S_{QiG3} + S_{QiG4}) \quad (13)$$

where,

S_{QI} = Score of bidder *i* with respect to quality success

$\mathrm{P_c}$ = Priority of quality success (survey results = 0.413)

S_{QiG1}= Score of bidder *i* with respect to group 1 criteria when quality success is evaluated

S_{QiG2}= Score of bidder *i* with respect to group 2 criteria when quality success is evaluated

S_{QiG3}= Score of bidder *i* with respect to group 3 criteria when quality success is evaluated

S_{QiG4}= Score of bidder *i* with respect to group 4 criteria when quality success is evaluated

Equation (14) is used to calculate the Score of contractor *i* with respect to Group 1 Criteria when Quality success is evaluated ($\mathrm{S_{QiG1}}$)

$$S_{QiG1} = \sum_{j=1}^{4} \mathrm{E_{j-Q}} \cdot S_{ij} \quad (14)$$

$$= \mathrm{E_{1-Q}} \cdot S_{i1} + \mathrm{E_{2-Q}} \cdot S_{i2} + \mathrm{E_{3-Q}} \cdot S_{i3} + \mathrm{E_{4-Q}} \cdot S_{i4}$$

where,

$\mathrm{E_{j\text{-}Q}}$ = Effect of criteria *j* on quality success

S_{ij} = Score of contractor *i* in criteria *j* from 1 to 10 (1 poor – 10 perfect)

$\mathrm{E_{1\text{-}Q}}$= Effect of current workload criteria on quality success (survey results = 0.033)

S_{i1} = Score of bidder *i* in current workload criteria - from 1 to 10

$E_{2\text{-}Q}$ = Effect of financial stability criteria on quality success (survey results = 0.051)

S_{i2} = Score of bidder *i* in Financial Stability criteria - from 1 to 10

$E_{3\text{-}Q}$= Effect of equipment availability criteria on quality success (survey results = 0.04)

S_{i3} = Score of bidder *i* in equipment availability criteria - from 1 to 10

$E_{4\text{-}Q}$= Effect of labor availability criteria on quality success (survey results = 0.042)

S_{i4} = Score of bidder *i* in labor availability criteria - from 1 to 10

Using survey results, Equation (14) will be as follows:

$$S_{QiG1} = \sum_{j=1}^{4} \mathrm{E_{j-Q}} \cdot S_{ij}$$

$$= \mathrm{E_{1-Q}} \cdot S_{i1} + \mathrm{E_{2-Q}} \cdot S_{i2} + \mathrm{E_{3-Q}} \cdot S_{i3} + \mathrm{E_{4-Q}} \cdot S_{i4}$$

$$= 0.033 \cdot S_{i1} + 0.051 \cdot S_{i2} + 0.04 \cdot S_{i3} + 0.042 \cdot S_{i4}$$

Equation (15) is used to calculate the Score of bidder *i* with respect to group 2 criteria when quality success is evaluated (S_{QiG2})

$$S_{QiG2} = \sum_{j=5}^{8} \mathrm{E_{j-Q}} \cdot S_{ij} \qquad (15)$$

$$= \mathrm{E_{5-Q}} \cdot S_{i5} + \mathrm{E_{6-Q}} \cdot S_{i6} + \mathrm{E_{7-Q}} \cdot S_{i7} + \mathrm{E_{8-Q}} \cdot S_{i8}$$

where,

$E_{5\text{-}Q}$ = Effect of number and scale of completed projects criteria on quality success (survey results = 0.05)

S_{i5} = Score of bidder *i* in number and scale of completed projects criteria - from 1 to 10

$E_{6\text{-}Q}$ = Effect of past performance (time and cost) criteria on quality success (survey results = 0.073)

S_{i6} = Score of bidder *i* in past performance (time and cost) criteria - from 1 to 10

$E_{7\text{-}Q}$ = Effect of past safety performance criteria on quality success (survey results = 0.048)

S_{i7} = Score of bidder *i* in past safety performance criteria - from 1 to 10

$E_{8\text{-}Q}$= Effect of past quality performance criteria on quality success (survey results = 0.06)

S_{i8} = Score of bidder *i* in past quality performance criteria - from 1 to 10

Using survey results, Equation (15) will be as follows:

$$S_{QiG2} = \sum_{j=5}^{8} \mathrm{E_{j-Q}} \cdot S_{ij}$$

$$= \mathrm{E_{5-Q}} \cdot S_{i5} + \mathrm{E_{6-Q}} \cdot S_{i6} + \mathrm{E_{7-Q}} \cdot S_{i7} + \mathrm{E_{8-Q}} \cdot S_{i8}$$

$$= 0.05 \cdot S_{i5} + 0.073 \cdot S_{i6} + 0.048 \cdot S_{i7} + 0.06 \cdot S_{i8}$$

Equation (16) is used to calculate the score of bidder *i* with respect to group 3 criteria when quality success is evaluated (S_{QiG3})

$$S_{QiG3} = \sum_{j=9}^{12} \mathrm{E_{j-Q}} \cdot S_{ij} \qquad (16)$$

$$= \mathrm{E_{9-Q}} \cdot S_{i9} + \mathrm{E_{10-Q}} \cdot S_{i10} + \mathrm{E_{11-Q}} \cdot S_{i11} + \mathrm{E_{12-Q}} \cdot S_{i12}$$

where,

$E_{9\text{-}Q}$ = Effect of number and qualifications of key personnel criteria on quality success (survey results = 0.109)

S_{i9} = Score of bidder *i* in number and qualifications of key personnel criteria - from 1 to 10

$E_{10\text{-}Q}$ = Effect of project controls capability criteria on quality success (survey results = 0. 143)

S_{i10} = Score of bidder *i* in project controls capability criteria - from 1 to 10

$E_{11\text{-}Q}$ = Effect of communication and documentation criteria on quality success (survey results = 0.1)

S_{i11} = Score of bidder *i* in communication and documentation criteria - from 1 to 10

$E_{12\text{-}Q}$ = Effect of risk management capability criteria on quality success (survey results = 0.071)

S_{i12} = Score of bidder *i* in risk management capability criteria - from 1 to 10

Using survey results, Equation (16) will be as follows:

$$S_{QiG3} = \sum_{j=9}^{12} \mathrm{E_{j-Q}} \cdot S_{ij}$$

$$= \mathrm{E_{9-Q}} \cdot S_{i9} + \mathrm{E_{10-Q}} \cdot S_{i10} + \mathrm{E_{11-Q}} \cdot S_{i11} + \mathrm{E_{12-Q}} \cdot S_{i12}$$

$$= 0.109 \cdot S_{i9} + 0.143 \cdot S_{i10} + 0.1 \cdot S_{i11} + 0.071 \cdot S_{i12}$$

Equation (17) is used to calculate the Score of bidder *i* with respect to group 4 criteria when quality success is evaluated (S_{QiG4})

$$S_{QiG4} = \sum_{j=13}^{16} \mathrm{E_{j-Q}} \cdot S_{ij} \qquad (17)$$

$$= \mathrm{E_{13-Q}} \cdot S_{i13} + \mathrm{E_{14-Q}} \cdot S_{i14} + \mathrm{E_{15-Q}} \cdot S_{i15} + \mathrm{E_{16-Q}} \cdot S_{i16}$$

where,

$E_{13\text{-}Q}$ = Effect of use of sustainable construction practices criteria on quality success (survey results = 0.057)

S_{i13} = Score of bidder *i* in use of sustainable construction practices criteria - from 1 to 10

$E_{14\text{-}Q}$= Effect of social impact (Corporate and Social Responsibility CSR) criteria on quality success (survey results = 0.034)

S_{i14} = Score of bidder *i* in social impact (Corporate and Social Responsibility CSR) criteria - from 1 to 10

$E_{15\text{-}Q}$ = Effect of image and reputation criteria on quality success (survey results = 0.035)

S_{i15} = Score of bidder *i* in image and reputation criteria - from 1 to 10

$E_{16\text{-}Q}$ = Effect of use of technology criteria on quality success (survey results = 0.052)

S_{i16} = Score of bidder *i* in use of technology criteria - from 1 to 10

Using survey results, Equation (17) will be as follows:

$$S_{QiG4} = \sum_{j=13}^{16} \mathrm{E_{j-Q}} \cdot S_{ij}$$

$$= \mathrm{E_{13-Q}} \cdot S_{i13} + \mathrm{E_{14-Q}} \cdot S_{i14} + \mathrm{E_{15-Q}} \cdot S_{i15} + \mathrm{E_{16-Q}} \cdot S_{i16}$$

$$= 0.057 \cdot S_{i13} + 0.034 \cdot S_{i14} + 0.035 \cdot S_{i15} + 0.052 \cdot S_{i16}$$

5.3 Case Study

A G+1 villa project in Alkhazamyah Area, Sharjah, UAE, has been tendered to three contractors. The project manager received the three bids and started the evaluation process. The project manager decided to evaluate both financial and nonfinancial factors in order to provide a solid assessment to the client. Hence, the project manager decided to use the forecasting model to predict project success based on the contractors' characteristics. Table 5.1 summarizes the evaluator's scores for financial and non-financial criteria for the three bidders.

Using the equations in Section 5.2, and the scores in Table 5.1 the success score for bidder 1 will be calculated below in order to serve as an example which will help in using the model.

Table 5.1 Evaluator scores for financial and non-financial criteria of the 3 bidders

	Criteria	**Bidder 1 i=1**	**Bidder 2 i=2**	**Bidder 3 i=3**
	Financial			
S_{Fi}	Bid price*	10	9	6
	Non- Financial **			
S_{i1}	Current Workload	8	8	7
S_{i2}	Financial Stability	7	7	9
S_{i3}	Equipment Availability	5	7	7
S_{i4}	Labor Availability	4	8	9
S_{i5}	Number and Scale of Completed Projects	5	8	7
S_{i6}	Past Performance (Time and Cost)	6	7	8
S_{i7}	Past Safety Performance	6	8	7
S_{i8}	Past Quality Performance	6	8	8
S_{i9}	Number and Qualifications of key Personnel	5	8	8
S_{i10}	Project Controls Capability	4	9	8
S_{i11}	Communication and Documentation	5	8	9
S_{i12}	Risk Management Capability	6	8	9
S_{i13}	Use of Sustainable Construction Practices	7	7	8
S_{i14}	Social Impact (Corporate and Social Responsibility CSR)	9	7	8
S_{i15}	Image and Reputation	8	9	8
S_{i16}	Use of Technology (e.g. BIM)	6	8	7

*The bid prices that he got were as follows: 1.5M, 1.6M and 1.8M. The score of each of the contractor in the financial factor is subjective.
**As for the contractor nonfinancial factor evaluation, the project manager used the tips provided in chapter 3 for each of the criteria as a tool to evaluated those factor and give them the accurate score.

Bidder 1

Using Equation (13)-(17), the score of bidder 1 in terms of quality success (S_{Q1}) can be calculated as follows:

From Equation (17):

$$S_{Q1G4} = \sum_{j=13}^{16} \mathrm{E_{j-Q}} \cdot S_{1j}$$

$$= \mathrm{E_{13-Q}} \cdot S_{1-13} + \mathrm{E_{14-Q}} \cdot S_{1-14} + \mathrm{E_{15-Q}} \cdot S_{1-15} + \mathrm{E_{16-Q}} \cdot S_{1-16}$$

$$= 0.057 \cdot S_{1-13} + 0.034 \cdot S_{1-14} + 0.035 \cdot S_{1-15} + 0.052 \cdot S_{1-16}$$

$$=0.057 \cdot \mathbf{7}+0.034 \cdot \mathbf{9}+0.035 \cdot \mathbf{8}+0.052 \cdot \mathbf{6}$$

$$= \underline{\mathbf{1.297}}$$

From Equation (16):

$$S_{Q1G3} = \sum_{j=9}^{12} \mathrm{E_{j-Q}} \cdot S_{ij}$$

$$=\mathrm{E_{9-Q}} \cdot S_{1-9}+\mathrm{E_{10-Q}} \cdot S_{1-10}+\mathrm{E_{11-Q}} \cdot S_{1-11}+\mathrm{E_{12-Q}} \cdot S_{1-12}$$

$$= 0.109 \cdot S_{1-9}+0.143 \cdot S_{1-10}+0.1 \cdot S_{1-11}+0.071 \cdot S_{1-12}$$

$$= 0.109 \cdot \mathbf{5}+0.143 \cdot \mathbf{4}+0.1 \cdot \mathbf{5}+0.071 \cdot \mathbf{6}$$

$$= \underline{\mathbf{2.043}}$$

From Equation (15):

$$S_{Q1G2} = \sum_{j=5}^{8} \mathrm{E_{j-Q}} \cdot S_{ij}$$

$$=\mathrm{E_{5-Q}} \cdot S_{1-5}+\mathrm{E_{6-Q}} \cdot S_{1-6}+\mathrm{E_{7-Q}} \cdot S_{1-7}+\mathrm{E_{8-Q}} \cdot S_{1-8}$$

$$= 0.05 \cdot S_{1-5}+0.073 \cdot S_{1-6}+0.048 \cdot S_{1-7}+0.06 \cdot S_{1-8}$$

$$= 0.05 \cdot \mathbf{5}+0.073 \cdot \mathbf{6}+0.048 \cdot \mathbf{6}+0.06 \cdot \mathbf{6}$$

$$= \underline{\mathbf{1.336}}$$

From Equation (14):

$$S_{Q1G1} = \sum_{j=1}^{4} \mathrm{E_{j-Q}} \cdot S_{ij}$$

$$=\mathrm{E_{1-Q}} \cdot S_{1-1}+\mathrm{E_{2-Q}} \cdot S_{1-2}+\mathrm{E_{3-Q}} \cdot S_{1-3}+\mathrm{E_{4-Q}} \cdot S_{1-4}$$

$$= 0.033 \cdot 8+0.051 \cdot 7+0.04 \cdot 5+0.042 \cdot 4$$

$$= \underline{\mathbf{0.989}}$$

From Equation (13):

$$S_{Q1}=\mathrm{P_Q} \cdot (S_{Q1G1} + S_{Q1G2} + S_{Q1G3} + S_{Q1G4})$$

$$= 0.413 \cdot (0.989 + 1.336 + 2.043 + 1.297)$$

$$= \underline{\mathbf{2.340}}$$

Using Equation (8)-(12), The score of bidder 1 in terms of time success (S_{Ti}) can be calculated:

From Equation (12):

$$S_{T1G4} = \sum_{j=13}^{16} \mathrm{E_{j-T}} \cdot S_{1j}$$

$$=\mathrm{E_{13-T}} \cdot S_{1-13}+\mathrm{E_{14-T}} \cdot S_{1-14}+\mathrm{E_{15-T}} \cdot S_{1-15}+\mathrm{E_{16-T}} \cdot S_{1-16}$$

$$= 0.06 \cdot \mathbf{7}+0.031 \cdot \mathbf{9}+0.031 \cdot \mathbf{8}+0.057 \cdot \mathbf{6}$$

$$= \underline{\mathbf{1.289}}$$

From Equation (11):

$$S_{T1G3} = \sum_{j=9}^{12} \mathrm{E_{j-T}} \cdot S_{1j}$$

$$= E_{9-C} \cdot S_{1-9} + E_{10-C} \cdot S_{1-10} + E_{11-C} \cdot S_{1-11} + E_{12-C} \cdot S_{1-12}$$

$$= 0.115 \cdot \mathbf{5} + 0.134 \cdot \mathbf{4} + 0.089 \cdot \mathbf{5} + 0.074 \cdot \mathbf{6}$$

$$= \underline{\mathbf{2.00}}$$

From Equation (10):

$$S_{T1G2} = \sum_{j=5}^{8} E_{j-T} \cdot S_{1j}$$

$$= E_{5-T} \cdot S_{1-5} + E_{6-T} \cdot S_{1-6} + E_{7-T} \cdot S_{1-7} + E_{8-T} \cdot S_{1-8}$$

$$= 0.047 \cdot \mathbf{5} + 0.08 \cdot \mathbf{6} + 0.046 \cdot \mathbf{6} + 0.067 \cdot \mathbf{6}$$

$$= \underline{\mathbf{1.393}}$$

From Equation (9):

$$S_{T1G1} = \sum_{j=1}^{4} E_{j-T} \cdot S_{1j}$$

$$= E_{1-T} \cdot S_{1-1} + E_{2-T} \cdot S_{1-2} + E_{3-T} \cdot S_{1-3} + E_{4-T} \cdot S_{1-4}$$

$$= 0.029 \cdot \mathbf{8} + 0.056 \cdot \mathbf{7} + 0.042 \cdot \mathbf{5} + 0.043 \cdot \mathbf{4}$$

$$= \underline{\mathbf{1.006}}$$

From Equation (8):

$$S_{T1} = P_T \cdot (S_{T1G1} + S_{T1G2} + S_{T1G3} + S_{T1G4})$$

$$= 0.27 \cdot (1.006 + 1.393 + 2.00 + 1.289)$$

$$= \underline{\mathbf{1.536}}$$

Using Equation 3-7, The score of bidder 1 in terms of cost success (S_{C1}) can be calculated:

From Equation (7):

$$S_{C1G4} = \sum_{j=13}^{16} E_{j-C} \cdot S_{1j}$$

$$= E_{13-C} \cdot S_{1-13} + E_{14-C} \cdot S_{1-14} + E_{15-C} \cdot S_{1-15} + E_{16-C} \cdot S_{1-16}$$

$$= 0.055 \cdot \mathbf{7} + 0.028 \cdot \mathbf{9} + 0.03 \cdot \mathbf{8} + 0.055 \cdot \mathbf{6}$$

$$= \underline{\mathbf{1.207}}$$

From Equation (6):

$$S_{C1G3} = \sum_{j=9}^{12} E_{j-C} \cdot S_{1j}$$

$$= E_{9-C} \cdot S_{1-9} + E_{10-C} \cdot S_{1-10} + E_{11-C} \cdot S_{1-11} + E_{12-C} \cdot S_{1-12}$$

$$= 0.046 \cdot \mathbf{5} + 0.093 \cdot \mathbf{4} + 0.042 \cdot \mathbf{5} + 0.088 \cdot \mathbf{6}$$

$$= \underline{\mathbf{2.047}}$$

From Equation (5):

$$S_{C1G2} = \sum_{j=5}^{8} E_{j-C} \cdot S_{1j}$$

$$= E_{5-C} \cdot S_{1-5} + E_{6-C} \cdot S_{1-6} + E_{7-C} \cdot S_{1-7} + E_{8-C} \cdot S_{1-8}$$

$$= 0.046 \cdot \mathbf{5} + 0.093 \cdot \mathbf{6} + 0.042 \cdot \mathbf{6} + 0.088 \cdot \mathbf{6}$$

$$= \underline{\mathbf{1.568}}$$

From Equation (4):

$$S_{C1G1} = \sum_{j=1}^{4} \mathrm{E_{j-C}} \cdot S_{1j}$$

$$= \mathrm{E_{1-C}} \cdot S_{1-1} + \mathrm{E_{2-C}} \cdot S_{1-2} + \mathrm{E_{3-C}} \cdot S_{1-3} + \mathrm{E_{4-C}} \cdot S_{1-4}$$

$$= 0.023 \cdot \mathbf{8} + 0.053 \cdot \mathbf{7} + 0.034 \cdot \mathbf{5} + 0.036 \cdot \mathbf{4}$$

$$= \underline{\mathbf{0.869}}$$

From Equation (3):

$$S_{C1} = \mathrm{P_C} \cdot (S_{C3G1} + S_{C3G2} + S_{C3G3} + S_{C3G4})$$

$$= 0.317 \cdot (0.869 + 1.568 + 2.047 + 1.207)$$

$$= \underline{\mathbf{1.804}}$$

Using the results from Equations (13), (8) and (3) into Equation (2) will enable us to calculate the score of bidder *1* with respect to non-financial factors (S_{NFi}).

$$S_{NF1} = S_{C1} + S_{T1} + S_{Q1}$$

$$= 1.804 + 1.536 + 2.340$$

$$= \underline{5.68}$$

The evaluator decided to give bidder 1 a score of 10 in the financial factors (S_{f1}=10 -Subjective) since the contractor had the lowest price. Using Equation (1), the success score for contractor 1 was as follows:

$$SS_i = \mathrm{C_F} \cdot S_{Fi} + \mathrm{C_{NF}} \cdot S_{NFi}$$

$$SS_i = 0.513 \cdot 10 + 0.487 \cdot 5.68$$

$$= \underline{\mathbf{7.90}}$$

The importance of the model is displayed through analyzing the case study results. If the evaluator was only focusing on the financial aspect of the assessment, then he/she would definitely select bidder 1 since bidder 1 was the lowest bidder (S_F=10). If the nonfinancial criteria were evaluated neglecting the effect of the financial ones, then bidder 3 would be the selection of the evaluator for this project as the non-financial criteria for bidder 3 was the best (S_{NF}=8.05). The summary of the evaluation of the 3 bidders are shown in the Table 5.2 ,5.3and 5.4:

Table 5.2 Contractor 1 evaluation summary

j	Non- Financial Factors	$E_{j\text{-}C}$	$E_{j\text{-}T}$	$E_{j\text{-}Q}$	S_{1j}	P_C	P_T	P_Q	$E_{j\text{-}C}* S_{1j}$		$E_{j\text{-}T}* S_{1j}$		$E_{j\text{-}Q}* S_{1j}$	
1	Current Workload	0.023	0.029	0.033	**8**	0.317	0.27	0.413	0.184		0.232		0.264	
2	Financial Stability	0.053	0.056	0.051	**7**				0.371		0.392		0.357	
3	Equipment Availability	0.034	0.042	0.04	**5**				0.170	S_{C1G1}	0.210	S_{T1G1}	0.200	S_{Q1G1}
4	Labor Availability	0.036	0.043	0.042	**4**				0.144	0.869	0.172	1.006	0.168	0.989
5	Number and Scale of Completed Projects	0.046	0.047	0.05	**5**				0.230		0.235		0.250	
6	Past Performance (Time and Cost)	0.093	0.08	0.073	**6**				0.558		0.480		0.438	
7	Past Safety Performance	0.042	0.046	0.048	**6**				0.252	S_{C1G2}	0.276	S_{T1G2}	0.288	S_{Q1G2}
8	Past Quality Performance	0.088	0.067	0.06	**6**				0.528	1.568	0.402	1.393	0.360	1.336
9	Number and Qualifications of key Personnel	0.103	0.115	0.109	**5**				0.515		0.575		0.545	
10	Project Controls Capability	0.126	0.134	0.143	**4**				0.504		0.536		0.572	
11	Communication and Documentation	0.094	0.089	0.1	**5**				0.470	S_{C1G3}	0.445	S_{T1G3}	0.500	S_{Q1G3}
12	Risk Management Capability	0.093	0.074	0.071	**6**				0.558	2.047	0.444	2.000	0.426	2.043
13	Use of Sustainable Construction Practices	0.055	0.06	0.057	**7**				0.385		0.420		0.399	
14	Social Impact (Corporate and Social Responsibility CSR)	0.028	0.031	0.034	**9**				0.252		0.279		0.306	
15	Image and Reputation	0.03	0.031	0.035	**8**				0.240	S_{C1G4}	0.248	S_{T1G4}	0.280	S_{Q1G4}
16	Use of Technology (e.g. BIM)	0.055	0.057	0.052	**6**				0.330	1.207	0.342	1.289	0.312	1.297
										S_{C1}		S_{T1}		S_{Q1}
										1.804		1.536		2.340
						C_F		C_{NF}		S_{NF1}		S_{F1}		SS_1
						0.51		0.49		5.68		**10**		7.9

Table 5.3 Contractor 2 evaluation summary

j	**Non- Financial Factors**	$E_{j\text{-}C}$	$E_{j\text{-}T}$	$E_{j\text{-}Q}$	S_{2j}	P_C	P_T	P_Q	$E_{j\text{-}C}* S_{2j}$		$E_{j\text{-}T}* S_{2j}$		$E_{j\text{-}Q}* S_{2j}$	
1	Current Workload	0.023	0.029	0.033	**8**	0.317	0.27	0.413	0.184		0.232		0.264	
2	Financial Stability	0.053	0.056	0.051	**7**				0.371		0.392		0.357	
3	Equipment Availability	0.034	0.042	0.04	**7**				0.238	S_{C2G1}	0.294	S_{T2G1}	0.28	S_{Q2G1}
4	Labor Availability	0.036	0.043	0.042	**8**				0.288	1.081	0.344	1.262	0.336	1.237
5	Number and Scale of Completed Projects	0.046	0.047	0.05	**8**				0.368		0.376		0.4	
6	Past Performance (Time and Cost)	0.093	0.08	0.073	**7**				0.651		0.56		0.511	
7	Past Safety Performance	0.042	0.046	0.048	**8**				0.336	S_{C2G2}	0.368	S_{T2G2}	0.384	S_{Q2G2}
8	Past Quality Performance	0.088	0.067	0.06	**8**				0.704	2.059	0.536	1.84	0.48	1.775
9	Number and Qualifications of key Personnel	0.103	0.115	0.109	**8**				0.824		0.92		0.872	
10	Project Controls Capability	0.126	0.134	0.143	**9**				1.134		1.206		1.287	
11	Communication and Documentation	0.094	0.089	0.1	**8**				0.752	S_{C2G3}	0.712	S_{T2G3}	0.8	S_{Q2G3}
12	Risk Management Capability	0.093	0.074	0.071	**8**				0.744	3.454	0.592	3.43	0.568	3.527
13	Use of Sustainable Construction Practices	0.055	0.06	0.057	**7**				0.385		0.42		0.399	
14	Social Impact (Corporate and Social Responsibility CSR)	0.028	0.031	0.034	**7**				0.196		0.217		0.238	
15	Image and Reputation	0.03	0.031	0.035	**9**				0.270	S_{C2G4}	0.279	S_{T2G4}	0.315	S_{Q2G4}
16	Use of Technology (e.g. BIM)	0.055	0.057	0.052	**8**				0.440	1.291	0.456	1.372	0.416	1.368
										S_{C2}		S_{T2}		S_{Q2}
										2.5		2.134		3.266
						C_F		C_{NF}		S_{NF2}		S_{F2}		SS_2
						0.51		0.49		7.9		**9**		8.46

Table 5.4 Contractor 3 evaluation summary

j	Non- Financial Factors	$E_{j\text{-}C}$	$E_{j\text{-}T}$	$E_{j\text{-}Q}$	S_{3j}	P_C	P_T	P_Q	$E_{j\text{-}C}* S_{3j}$		$E_{j\text{-}T}* S_{3j}$		$E_{j\text{-}Q}* S_{3j}$	
1	Current Workload	0.023	0.029	0.033	**7**	0.317	0.27	0.413	0.161		0.203		0.231	
2	Financial Stability	0.053	0.056	0.051	**9**				0.477		0.504		0.459	
3	Equipment Availability	0.034	0.042	0.04	**7**				0.238	S_{C3G1}	0.294	S_{T3G1}	0.28	S_{Q3G1}
4	Labor Availability	0.036	0.043	0.042	**9**				0.324	1.2	0.387	1.388	0.378	1.348
5	Number and Scale of Completed Projects	0.046	0.047	0.05	**7**				0.322		0.329		0.35	
6	Past Performance (Time and Cost)	0.093	0.08	0.073	**8**				0.744		0.64		0.584	
7	Past Safety Performance	0.042	0.046	0.048	**7**				0.294	S_{C3G2}	0.322	S_{T3G2}	0.336	S_{Q3G2}
8	Past Quality Performance	0.088	0.067	0.06	**8**				0.704	2.064	0.536	1.827	0.48	1.75
9	Number and Qualifications of key Personnel	0.103	0.115	0.109	**8**				0.824		0.92		0.872	
10	Project Controls Capability	0.126	0.134	0.143	**8**				1.008		1.072		1.144	
11	Communication and Documentation	0.094	0.089	0.1	**9**				0.846	S_{C3G3}	0.801	S_{T3G3}	0.9	S_{Q3G3}
12	Risk Management Capability	0.093	0.074	0.071	**9**				0.837	3.515	0.666	3.459	0.639	3.555
13	Use of Sustainable Construction Practices	0.055	0.06	0.057	**8**				0.44		0.48		0.456	
14	Social Impact (Corporate and Social Responsibility CSR)	0.028	0.031	0.034	**8**				0.224		0.248		0.272	
15	Image and Reputation	0.03	0.031	0.035	**8**				0.24	S_{C3G4}	0.248	S_{T3G4}	0.28	S_{Q3G4}
16	Use of Technology (e.g. BIM)	0.055	0.057	0.052	**7**				0.385	1.289	0.399	1.375	0.364	1.372
										S_{C3}		S_{T3}		S_{Q3}
										2.558		2.173		3.314
						C_F		C_{NF}		S_{NF3}		S_{F3}		SS_3
						0.51		0.49		8.05		**5**		6.48

Using the model would enable us to evaluate both the financial and the nonfinancial criteria of the bidders which result in a recommendation to hire bidder 2 for the job as the success score of bidder 2 was 8.46 in compared to bidder 1 (SS_1=7.9) and bidder 3 (SS_3=6.48)

Chapter 6. Conclusion and Future Work

6.1 Conclusion

In this Thesis, a forecasting model has been developed based on the collected data. Forty-five professional personnel participated in a survey whose aim was to provide a direct relation between the nonfinancial characteristics and project success factors. The nonfinancial characteristics were gathered from previous literature, and then an extensive shortlisting process were conducted. Sixteen characteristics were evaluated against three main success factors: time, cost and quality. The results of the survey provide the bases for the model. The results explained the effect of each of the criteria with the three success factors. Group three with the project management capabilities were found to be the main characteristics that affect all successes factors (time, cost and quality). Moreover, the results provided a ranking of the criteria based on their effect on the each of the success factors. In addition, nonfinancial and financial factors were compared to each other with respect to their importance to the evaluator of the contractors. The results showed that nonfinancial factors almost have the same effect on the project success as financials ones. All the results were compiled in one equation (model) that is assumed to help in predicting the contractors' success in a project based on the contactor's characteristics without neglecting the bid price (Financial Factor).

6.2 Future Work

The model can be tested against empirical data from a completed project with a failure. Future work is needed to see if the contractor failure can be predicted before starting that project. Although chapter 3 provided a general outline on what bases the scoring of each criterion was done, evaluation guidelines can be developed. A well-defined scoring methodology and sub criteria can be created. These guidelines and such a methodology can help the evaluator to have a better assessment for each of the criteria, which will indeed enhance the results of the model. Furthermore, a study on the effect of the construction type/field on the results of the survey is also necessary. Do residential projects share the same effect of contractor characteristics on project success with road construction? The model can also be tested in another region to study whether the effects are related to the uniqueness of the UAE construction industry or it is unified world-wide.

In addition, a study can be conducted on whether the years of experience, projects types, the average sizes of the projects completed in terms of money and the role in the projects (consultant, contractor, client) have an impact on the overall decision.

6.3 Limitation

The proposed model is useful for clients since it helps in selecting the most appropriate contractor that has the highest chance of achieving project success. There are some limitations. Validation is one of the limitation in this model. In order to validate this model, it should be applied to several completed projects with success and failure history. This model is hard to validate for the following two reasons: the accessibility and the availability of data of completed projects specially the ones that have experienced failures and the duration needed to gather and analyze that information. The information shall include all data of participated bidders in that project along with detailed records of the project's failure in order to use the model for validation. Moreover, this model cannot evaluate startup contractors because most of the non-financial criteria data will not be available. Since the contractor is new in the market, the past performance and past experience group as an example can't be evaluated. The linearity of the proposed model simplifies the real applications of the model. In reality, those applications are more complex to be governed with a linear model. In addition, the model does not specify a minimum success score for the contactors to achieve in order to be considered in the evaluation process. For example, if the three evaluated contractors scored less than 5 in the success score, should we consider them as potential candidates to win the bid and proceed with the project with this low score, or other contractors should be invited. These limitations provide opportunities for future research projects.

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Vita

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