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Scrutinizing Competitiveness of Construction Companies Based on an Integrated Multi-Criteria Decision Making Model

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Abstract: The construction sector continues to experience significant challenges brought by new techniques and technologies. Hence, there is a dire need for construction companies to address critical issues concerning changing environmental conditions, construction innovations, market globalization and many other aspects, thereby enhancing their competitive edge. Thus, the primary goal for this research is to develop a multi-criteria decision making model that would consider and evaluate all essential factors in determining the competitiveness index of construction companies. In the developed model, three new pillars (3P) for competitiveness are introduced: (1) non-financial internal pillar; (2) non-financial external pillar; and (3) financial pillar. The 3P includes 6 categories and 26 factors that are defined and incorporated in the developed assessment model for the purpose of measuring the companies' competitiveness. The weights for the identified factors are computed using fuzzy analytical network process (FANP) to diminish the uncertainty inherited within the judgment of the respondents. The weight of factors and their affiliated performance scores are used as an input for the preference ranking organization method for enrichment evaluation (PROMETHEE II) technique. In this regard, PROMETHEE II is undertaken as a ranking technique to prioritize any given construction company by determining its respective competitiveness index. The developed model is validated through five cases studies that reveal its potential of illustrating detailed analysis with respect to the competitive ability of construction companies. A sensitivity analysis is carried out to determine the most influential factors that affect the competitiveness of construction companies. It is anticipated that the developed evaluation model can be used in the decision-making process by all parties involved in construction projects. For instance, contractors can leverage the evaluation model in taking better decisions pertinent to the markup values. In addition, it can benefit employers in the evaluation process of contractors.

Keywords: construction sector; competitiveness; multi-criteria decision making; fuzzy analytical network process; PROMETHEE II; sensitivity analysis

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1. Introduction

Efficient management and competitive capacity are key factors for the success of construction companies. In recent decades, applying technology to production processes has brought construction companies to a higher standard, reducing production time, increasing efficiency, and decreasing costs of production [1–5]. While most are still behind in

competition, a few have managed to incorporate digital techniques in their operations. Construction processes have adapted slowly to the technological advances and little progress has been recorded. In addition, globalization offers a platform for construction companies to be established, to innovate and to grow on the international market. It is a common notion that through globalization, companies are able to exploit distant markets and to own assets. For instance, a company situated in Japan can employ its resources internationally by letting the American Banking Network commit themselves to projects worldwide [6]. Hence, companies with better resources' management have the advantage in competing in the global market and gaining extra benefits [7].

Globalization enhances the level of competitiveness, challenging participants to equip themselves better in terms of innovative advantages to be able to withstand the fierce market conditions. For example, contractors in certain countries such as China could have cheap labor and superior management skills [8]. This could lead them to exploit opportunities in the global market and become more competent than other construction companies in rest of the world (e.g., Europe, America, and Australia). Similarly, Japanese contractors are experiencing stiff competition from their counterparts, such as Korea, England, and China, all of which have massive capital deposits, sophisticated technology, and technical expertise. To survive in such an environment, it is important to increase the competitive ability by re-thinking and re-evaluating competitiveness.

The construction industry has become more complicated due to the continuous changes and challenges. Competitiveness and management strategies in construction companies face various problems such as new markets, the skills of labor and changes in the environmental conditions. In this context, changes in the surrounding environment means that only those construction companies that adapt well will survive, providing an opportunity for them to realize more profits. These include enterprises with established proactive systems of adapting to rapid changes [9]. In addition, the current management methods are not sufficient to offer companies accurate and concrete information to help them position themselves strategically for competition. The traditional performance-measuring techniques concentrate on site activities at a project level, which cannot fully respond to the current challenges due to restrictions and limited factors. More factors must be considered to improve the competitive ability of construction companies. Checking, measuring and improving competitive ability is the best method to maintain success [10]. In light of the foregoing, this research aims at reducing this gap by providing a model that can help companies re-evaluate and restore their competitiveness in respect to critical issues in the business environment. It can also usher in a ranking of companies' competitiveness, relative to one another. Hence, the main objectives of the present research study lie in the following:

1. Study and identify the affecting critical success factors (CSFs) on the construction company's competitiveness;
2. Determine and develop a competitiveness index for construction companies based on industry type and company size.

2. Literature Review

This section describes the concept of competitiveness in construction companies. It also delineates some of the previous research studies carried out to evaluate the competitiveness of construction companies.

2.1. Competitiveness of Construction Companies

Competitiveness can be described as "the capability of a company to adopt with structural changes" [11]. Porter [12] stated that "despite the global acceptance of the importance of competitiveness, it still remains a concept which is not well defined". Moreover, the term can be elaborated as the degree to which a company can produce products and services that meet the requirements of the international market while expanding or maintaining the income of its staff and shareholders. Competitiveness is defined in the Longman Advanced

American Dictionary as the ability of a company to compete with others and desire to be more successful than others. It can also mean having the ability to continuously provide the services and products which consumers can obtain from other competitors [13]. There are several levels of competitiveness. The national level features as one of the highest points of competitiveness, where notable institutions, such as the International Institute of Management Development (IMD) and The World Economic Forum (WEF) publish their reports [14]. The initiative is conducted on an annual basis to measure the competitive nature of construction companies. The reports offered various definitions of competitiveness. They identified, calculated and surveyed factors of competitiveness at a national level. In addition, construction companies need to conduct a well-founded processing of their data for reliable measurement and appraisal of their competitiveness levels [15,16].

At the industries' level, detailed analyses are conducted on industries. They also develop competitiveness theories concerning organizations, focusing solely on their competitive nature. This calls for the establishment of competitiveness assessment research at the company level where companies develop their own personal strategies to sustain competition in the market and outperform their rivals. According to Lu et al. [17], companies also adjust their systems and resources to meet challenges in the external environment (competition). Competitive bidding leads to strategic decisions as well as improved performance and competitiveness for organizations.

2.2. Previous Research Studies

In recent decades, researchers and practitioners have devoted close attention to competitiveness in various sectors across the world. The growing importance of competition in the industry determines/predicts organizations' ability to sustain themselves during times of crisis as well as business performance. Warsawski [18] developed an orderly process to determine competitive strategies using a four-step methodology for strategic planning that examines the mission statement and analyzes the external environment, available resources and finally its competitive strategy. This approach relied on Porter's theory of differentiation, cost, leadership and focus. Chinowsky's [1] method assessed construction companies' competitiveness based on how they organize and manage seven areas: vision; goals; mission; knowledge resources; core competencies; education; markets; finance; and competition. The survey revealed areas of positive management (market awareness and technology) and others that require greater emphasis such as core competencies and education. Arslan and Kivrak [19] deployed a simple multi-attribute rating technique (SMART) to explore the critical success factors of construction companies. Findings showed financial conditions, business management and manager/owner characteristics as some of the factors providing sustainability. Additionally, this study concluded that achieving relevance on the international market requires the company to tame, understand and apply strategic management and planning principles in order to change management optimally and purposefully.

Tan [20] introduced an effective model that can help assess competitiveness in construction companies. This research studied revealed 10 critical success factors for enhanced performance which were: organizational structures; political environment; employee enhancements; process benchmarking; technical applications; evaluation and feedback; competitive strategy; inter-organizational relationships; management skills; environmental factors. As a strategic management tool, it emphasized the importance of organizational levels in managing construction companies. As per this research, organizations should focus on eight areas (mission, vision, goals, knowledge, core competencies, finance, competition, and markets) to enhance their competitiveness and transition smoothly in the wake of changing competitor and customer conditions. Nurisra et al. [21] studied the main factors that affect the competitiveness of medium-class contractor companies. In this regard, 41 critical success factors were identified based on a dataset gathered from 31 companies. The factors were divided into categories that involved organizational structure, relationship, bidding, financial capability, etc. Descriptive analysis was utilized to compute

the mean and total score of each of the factors. It was found that relationship is the most important category with a mean score of 4.52 while relationship with government is the most important factor with a mean score of 4.92.

Huda et al. [22] presented a model that aimed at studying the implications of industrial, internal and external factors on the competitiveness of construction companies. A Likert scale questionnaire was used as the basis of analyzing the competitiveness of large, medium and small construction companies. Hypothesis testing and factor analysis were implemented to test the influence of industrial, internal and external factors on the enterprise's performance and competitiveness. It was shown that the afore-mentioned factors exhibit a significant positive influence on the company's performance and competitiveness. Asgari et al. [23] introduced a model for the purpose of identifying the critical success factors of owner, contractor and consultant in the construction industry. A questionnaire survey was used to evaluate 41 critical success factors based on a five point linguistic scale. These factors were divided into five main clusters, namely project characteristics, contractual arrangement, human resources, interactive processes and financial characteristics. The Friedman test and scoring method were exploited to rank the critical success factors with regards to the three main pivots of the construction industry. It was derived that human resources is the most important cluster with regards to owners and contractors while project characteristics is the most important cluster with respect to consultants. The results also emphasized on the significance of contractor key personnel, realistic objectives and contractor track record.

Durdyev et al. [24] proposed an analytical hierarchy process approach for the evaluation of critical success factors of contractors. A questionnaire survey was designed to compare between 22 critical success factors based on a nine point linguistic scale. Findings of the developed approach showed that complexity of project, social/cultural environment and ability to make timely decisions are the important critical success factors with weights of 14.89%, 11.43% and 7.65%, respectively. Tripathi and Jha [25] presented a methodology to analyze the success factors of construction organizations. Parametric one sample *t*-test was performed to determine the most significant factors in the success of construction companies. The success attributes encompassed availability of quality staff, past experience, customer's satisfaction, financial soundness, etc. Factor analysis was then implemented to minimize the resulted success attributes into manageable ones which in turn resulted in the extraction of eight success attributes which were the availability of qualified staff, availability of resources and information flow, project factor, supply chain and leadership, experience and performance, top management's competence, effective cost control measures and favorable markets and marketing team.

Somiah et al. [26] defined the critical success strategies for competitive construction firms in developing countries. With the help of a questionnaire survey, they defined 21 critical success factors such as prices lower than competitors, being technologically independent, having a brand identity, maintaining clients' loyalty, etc. Using principal component analysis, the 21 factors were categorized into small groups, namely branding strategies, client-centered strategies, tender strategies and contract strategies. It was advised that stakeholders in construction firms would implement the identified strategies to improve their competitive advantage. Yang et al. [27] carried out a study to investigate the influential factors on general contractor's capability. In their study, fourteen factors were defined that have an influence on the competitiveness of general contractor enterprises. These factors involved financial capability, project management capacity, human resource management capacity, social influence, etc. Interpretive structural modeling was utilized to explore the interrelationship and correlation between the factors influencing a general contractor's competitiveness. The Matrice d' Impacts Croises Multiplication Appliqué a Classement algorithm was then implemented to categorize the factors with regards to their driving power and dependence power. It was revealed that the success in promoting general contractor's capability is highly dependent on the enterprise's culture.

Toan et al. [28] explored the critical factors implicating labor productivity in the construction industry from the project manager's perception. The identified factors were clustered into six groups, namely external, project, work condition, manpower, management and motivation. It was found that the ability of construction management, financial status of stakeholders, work discipline, design changes and timeliness of renumeration, highly impact on the construction labor productivity rates. Zeibote et al. [29] studied the influence of globalization on regional development and competitiveness. It was emphasized that regional competitiveness is affected by innovation and business factors. It was also inferred that countries with higher standards of globalization can sustain competitiveness in the market.

Dobrovolskienė and Pozniak [30] proposed a multi-criteria decision making (MCDM) model to scrutinize the sustainability aspects of real estate projects. In this context, a group of environmental, social and technological factors were studied such as use of renewable energy, safety of infrastructure, time of construction, economic benefit for the region, overall project quality and cost of technology. Then, simple additive weighting (SAW) and technique for order of preference by similarity to ideal solution (TOPSIS) were applied to compose a sustainability index. The results demonstrated that the emission of CO_2 was regarded as the important sustainability criteria followed by safety and well-being of workers and then employment of innovative technologies. In addition, it was found that SAW was less sensitive than TOPSIS to the changes in the weights of the sustainability criteria. Krulický et al. [31] analyzed the values of actual costs of equity paid in construction industry over the period 2016–2019. The analysis was carried out capitalizing on some statistical indicators such as median, average, dispersion and standard deviation. Analytical computations showed that the average values and median values of equity costs lay in the range of 29.35–37.81% and 16.43–24.24%, respectively.

Nassar and Strielkowski [32] investigated prominent factors and concepts influencing the transition into the green financial sector. In this context, hypothesis testing was carried out to look into the relationship between green management dimensions in the financial sector, and the relationship between green management aspects and green market expansion. It was argued that transitioning towards greener finance requires green managerial decisions, and the assessment of green competitiveness paves the way for green managerial structure of the company. Bozgulova et al. [33] reviewed the methods of cost management calculation in the construction industry. It was urged that an activity-based costing method needed to be applied alongside a traditional custom-made calculation method for more accurate cost accounting in construction. It was also advised that each responsible entity is recommended to compute the differences between possible and actual volumes of work on a frequent basis.

2.3. Overview of Multi-Criteria Decision Making Algorithms

Multi-criteria decision making was one of the rapidly growing areas of operational research over the last two decades [34]. It refers to a set of techniques that enables modeling and blending the performances of different alternatives over different pre-defined attributes into a composite index that can be utilized for sorting out alternatives and appending the best alternative [35,36]. There are several previously reported multi-criteria decision-making techniques in the literature, such as grey relational analysis [37], simple additive weighting [38], additive ratio assessment (ARAS) [39], new combinative distance-based assessment (CODAS) [40], multi-objective optimization on the basis of ratio analysis (MOORA) [41], complex proportional assessment (COPRAS) [42] and criteria importance through inter-criteria correlation (CRITIC) [43].

3. Methodology

The proposed competitiveness assessment model is designed in a way that alleviates limitations of previous works and addresses underlying challenges in construction companies. The framework of the proposed model is shown in Figure 1. The proposed model is composed of two main modules, namely weight interpretation and competitiveness prioritization. In the weight interpretation module, the first step is to review previous research studies and theories pertinent to competitiveness and to study the widely acknowledged multi-criteria decision-making algorithms. The next step is to identify the critical success factors for the competitive ability of construction companies from analysis of previous literature and consultation with experts through several meetings and interviews. The third step involves creating a questionnaire survey, where experts were approached to express their preference towards the importance of the critical success factors and to determine their respective thresholds.

The consistency ratio is computed for each pairwise comparison matrix provided by the respondents in order to assess the consistency of the entries of each pairwise comparisons. In this context, if the consistency ratio is less than 10%, an acceptable level of consistency is experienced. Otherwise, the pairwise comparison matrices need to be revised [44]. In the developed model, the considered pairwise comparison matrices in the subsequent computational procedures are the ones whose accomplished consistency ratio is less than 10%. The developed model deploys fuzzy analytical network processing for the purpose of calculating the relative importance weights of the factors that affect the competitiveness of construction companies. The Fuzzy Analytic Network process is selected because it proved its efficiency in a wide range of applications such as the condition assessment of bridge decks [45], municipal solid waste management [46], disaster resilience assessment in hospitals [47] and analysis of conflicts' causes in construction projects [48].

In the second module, the relative importance weights of the critical success factors alongside their threshold value serve as an input to feed the construction company competitiveness module. In this regard, the developed model relies on the PROMETHEE II algorithm to construct an integrated index for the evaluation and ranking of the competitiveness of construction companies. PROMETHEE II is selected because it is one of the widely utilized MCDM algorithms that has been successfully implemented in several engineering applications such as maintenance planning in residential complexes [49], evaluation of nearly zero-energy buildings [50], ranking of critical urban sub-catchments [51], prestress design of cable-strut structures [52] and optimizing resource allocation plans [53]. It is also able to provide robust decisions despite explicit perturbations in the weights of design attributes [54]. In addition, it is accompanied by low information loss [55,56]. A total of five case studies are studied to examine the developed competitiveness assessment model. A sensitivity analysis is undertaken to derive the most important critical success factors on the competitiveness of construction companies.

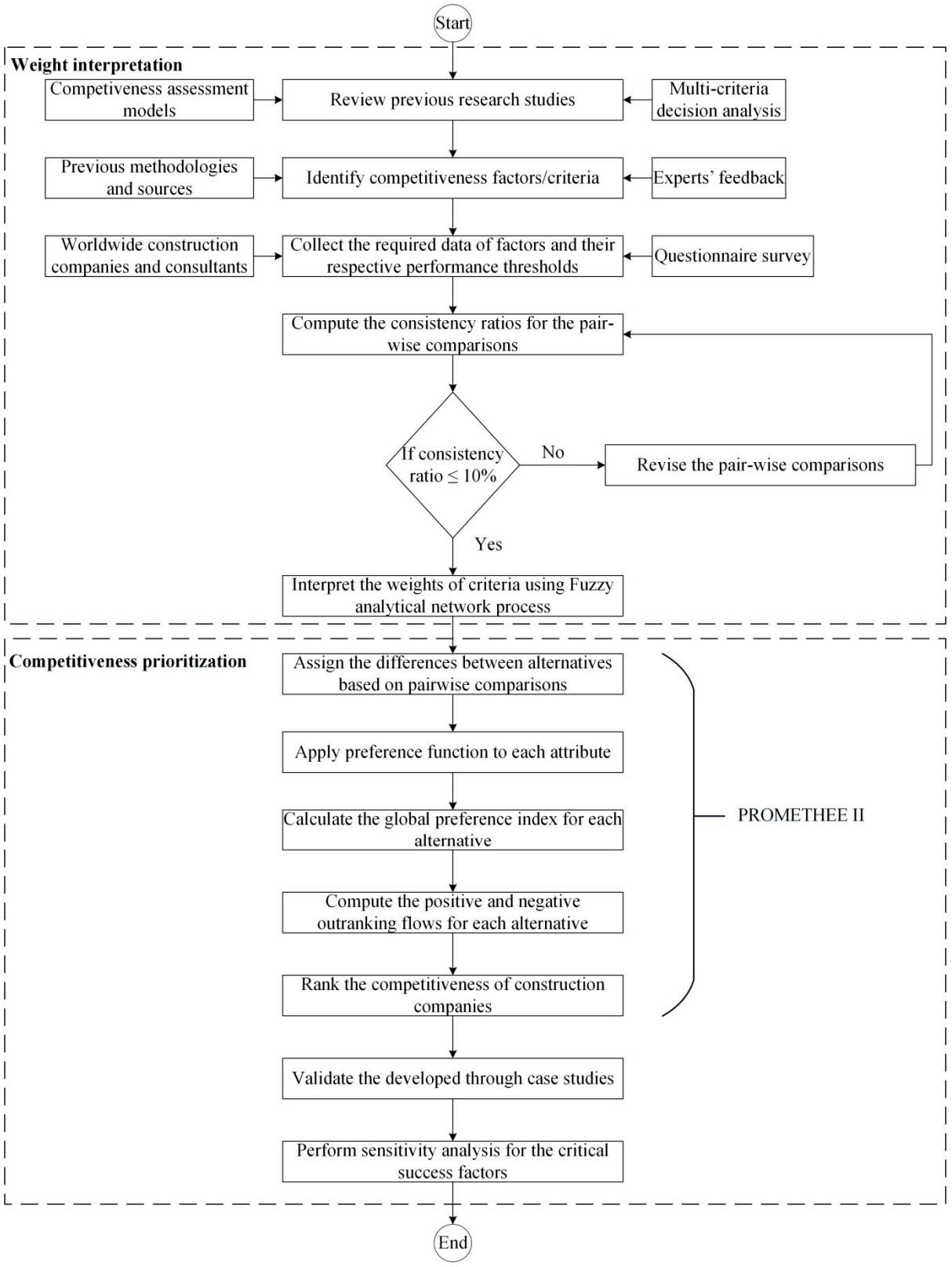


Figure 1. Framework of the developed competitiveness assessment model.

4. Model Development

This section describes the factors utilized to build the developed competitiveness assessment model. In addition, it explains the procedures of the utilized fuzzy analytical process and PROMETHEE II.

4.1. Factors Identification and Description

A literature review is carried out by going through previous research attempts and competitiveness theories to identify the influential factors on the competitiveness of construction companies. Moreover, several experts were approached through meetings to further solidify the generated list of critical success factors. In this regard, the assessment of construction companies' competitiveness is executed capitalizing on three main pillars of factors, namely internal, external and financial. The hierarchy of the targeted critical success factors is depicted in Figure 2. It is worth mentioning that descriptions for only a portion of the factors are reported due to space size limitations.

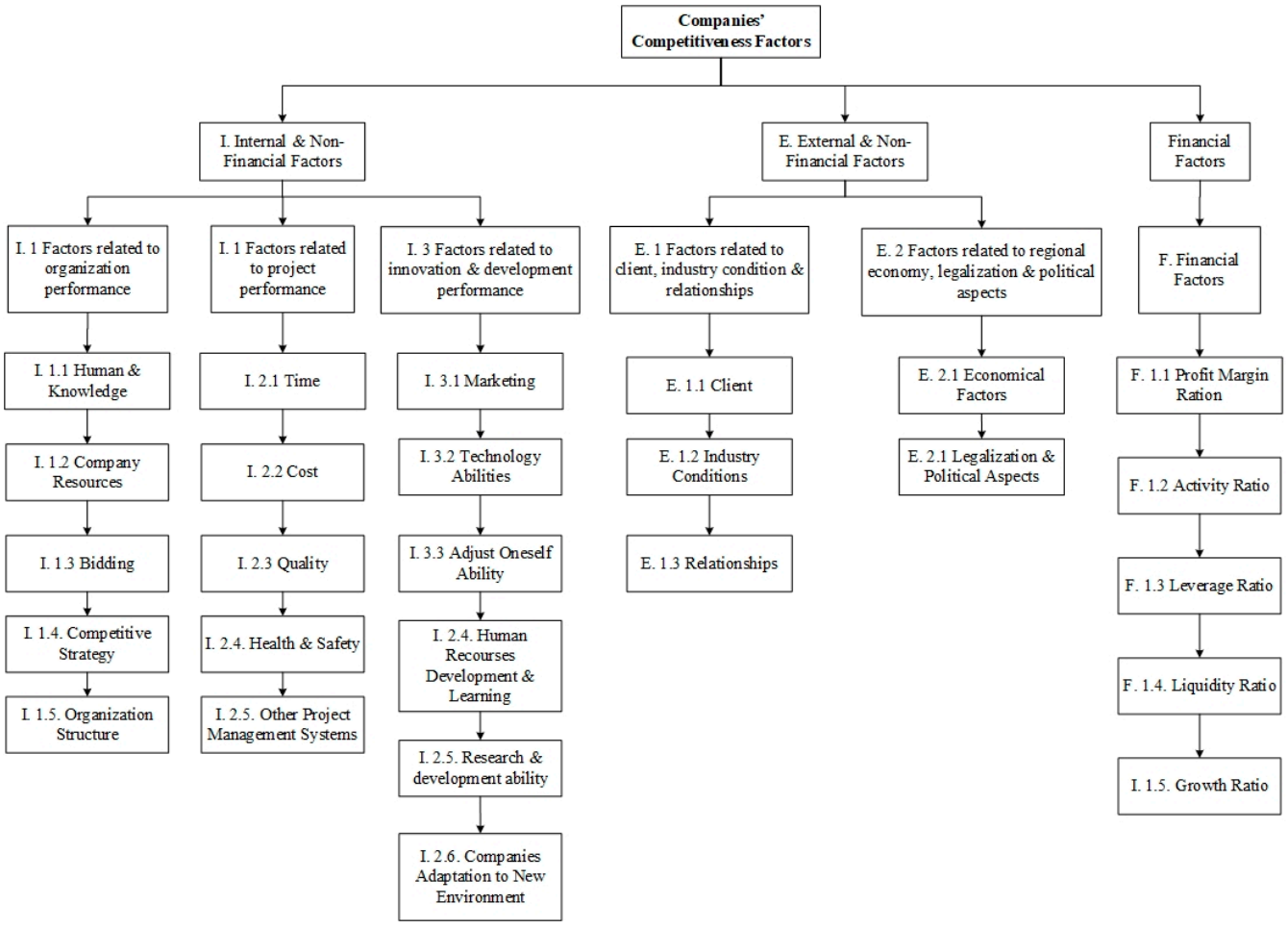


Figure 2. Hierarchy of critical success factors of companies' competitiveness.

4.1.1. Internal Pillar

The Internal Category includes those factors that the management works on with the intention of achieving goals. The Internal category includes three main categories. The first category includes factors related to organizational performance which construction organizations should take into consideration in labor skills and experts so as to establish a competitive strategy that is sufficiently feasible. Advances in technology and knowledge of construction firms require additional cooperation, education and the management of strategy at a company level. The first category involves the factors of humans and knowledge,

company resources, bidding, competitive strategy and organizational structure. The second category concerns project performance. Quality, time and costs are considered the main elements informing a construction firm's CSF model. Other project management models (e.g., Site Management, Risk Management, Claims Management, Contract Management, Logistics, and Supply Management) are vital for competitiveness studies. The project performance model is associated with some factors, such as: time, costs, quality, health and safety and project management systems.

The third category is essential in project management, and it includes innovation and development. In the course of responding to a competitive strategy, there should be special focus on innovation and development for the sake of consciousness. Firms should be concerned with making their employees more effective in their duties. They should also enhance the attractiveness of working conditions and improve recruitment processes. Further, employees should undergo consistent improvement through education and learning as these are some of the most important ingredients for developing new ways of achieving goals [57,58]. In addition, a company should also show exemplary performance in Information Communication and Technology to remain up to date with technological changes. The third category addresses some factors such as marketing, technological abilities, adjusting one's, human resources' development and learning, research and development ability and companies' adaptation to new environments.

➢ Humans and knowledge

Most competitiveness models consider human resources and the associated knowledge level as some of the most important elements in a company's competitive structure. It means that employees form a critical pillar in the competitiveness of firms in the construction enterprise [59];

➢ Company resources

Managers should place a high importance on the resources at the disposal of a company. This is a critical factor that assists companies to sustain competitiveness in complex environments. It insinuates that they should see to it that the company's resources are consumed optimally [60];

➢ Bidding

Construction firms tend to apply the competitive bidding model to obtain the best value and the kind of decision tools effective for supporting executives in making corporate decisions. As such, competitive companies include those that have enough resource availability, experience in bidding, and professionals for bidding [61];

➢ Competitive strategy

Every firm in the corporate world has a well-defined competitive strategy that outlines the mission, vision and goals of the company. They are used as tools for enhancing the competitiveness awareness in the course of improving their competitiveness. The three mentioned elements are the starting point, and once the company has established its strategy, it becomes able to confront a series of challenges in the course of operations [62];

➢ Organizational structure

In a globalization market, the upper management should consider the company's international standing. Communication protocols between departments, projects, staff, customers and stakeholders should be as clear as possible. All of this will affect the company's competitive ability and business. The role of team leaders throughout the departments is important for company competitiveness [63];

➢ Marketing

This is one of the critical factors to consider while addressing the competitive strategy of construction firms. Markets are constantly developing thanks to improvements in

technology. In such situations, there are a lot of orders from clients and their experience of the construction firm reflects its overall performance [64];

➢ Technology abilities

The innovation of technology and its application stand out as vital in achieving high levels of innovation and development. As such, firms should adopt the Internet in driving organizational operations and processes. One of the benefits of information technology is that it virtually connects customers, project managers and staff in a single network [65];

➢ Adjusting one's abilities

Flexibility and adjustment ability are vital factors for competitiveness in the present time. With the increase in globalization and competition, a construction company should adjust its management to be compatible with its environment [66];

➢ Human resources development

A company should invest in building up their human resources, attract labor to the company and carefully recruit staff. The stronger the team members are, the more competitive the company is [67].

4.1.2. External Pillar

The external pillar includes factors that originate from a firm's exterior environment (number of rivals, the level of public investment, etc.) and could have a limited or minimal influence on an organization. The external pillar has two different categories. The first category concerns clients, industry conditions and relationships. In sustaining the competitiveness ability of a company, construction companies are supposed to satisfy the demands of clients regarding their products and services [68,69].

The conditions of an industry should be addressed while analyzing the competitiveness of a given company. City regulations and laws, supplier demands and market conditions have a significant impact on the highly competitive company [70,71]. The relationships with suppliers, sub-contractors, consultants, designers, the public sector and government departments are supposed to be addressed within the shortest time possible [17,72]. The external pillar factors are divided into two categories. The first category encompasses factors pertinent to clients, industry conditions and relationships. The second category is oriented towards economic factors, legislation and political aspects.

➢ Clients

Competitiveness in the construction industry requires that companies strive to meet the preferences and tastes of their clients with respect to the quality of products and services that they deliver to them. The satisfaction level of clients can be gauged by the level of income realized from the sale of products and services [73];

➢ Industry conditions

The sub factors under the industry conditions that should be analyzed include matters such as the public sector, market laws and regulations, government departments and others [74];

➢ Relationships

The sub factors under the relationships that should be analyzed include things such as relationships with subcontractors, suppliers, designers, consultants, government departments and the public sector [75].

➢ Economic factors

Economic conditions are essential; the attractiveness of contracting in foreign currency and recession in the domestic construction market are vital for competitiveness [76,77];

➢ Legislation and political aspects

Company competitiveness is sensitive when it is faced by aspects such as corruption and lack of transparency, political instability, inconsistencies in government policies and laws, health and safety issues, procurement acts and legislation, lack of government guarantees and demand for construction [78,79].

4.1.3. Financial Pillar

The financial pillar is a group of factors that shows how the company is performing financially. In addition, it shows the rate at which companies have grown profits and is applied in the measurement of a company's ability to meet its debts in the short-term. Factors such as: profit margin ratio; activity ratio; leverage ratio; liquidity ratio; and growth ratio are an example of factors that affect the financial health of companies and their competitiveness level [80]. The afore-mentioned financial ratios are delineated in detail below.

➢ Ratio of profit margin

It is known as the ratio of return on sales. It is defined as a ratio of profitability that measures the level of net income obtained from each dollar of sales generated by comparing the net sales and net income of the company. In other words, the ratio of profit margin shows the percentage of sales left once the business has paid all expenses [81];

➢ Activity ratio

It is known as the management ratio or operating ratio; it measures a company's efficiency of using its assets to realize value [82];

➢ Leverage ratio

It is known as the debt to equity ratio. It offers a glimpse of company debt and the affiliated equity level. This ratio is useful for measuring the cost mix of a company and its impact on operating income. As such, companies that have a fixed cost that is relatively higher are positioned to earn more income because after the breakeven point, there is an increase in output. The income is also bound to grow since all costs have been incurred already [83,84];

➢ Liquidity ratio

Liquidity ratio is a company's ability to meet underlying financial obligations. This ratio is used for measuring the ability of a company to meet its debts in the short-term [85];

➢ Growth ratio

Net income growth features as the percentage gain/loss realized from net income on an annual basis. It is a good measure for determining how companies grow their revenue [86].

4.2. Fuzzy Analytic Network Process

Multi-Criteria Decision Making methods help decision makers and technical experts to determine the optimum strategic choice. Saaty [21] developed a multi-criteria decision support methodology, analytical hierarchy process (AHP), which belongs to the North American School. Saaty (2001) [87] presented analytical network process (ANP) as an extension to overcome AHP limitations by considering interdependencies between the criteria, which helps to measure the relative effect of one of two elements over the other. ANP output is the relative importance of the criteria based on experts' opinions. According to Kahraman et al. [88], verbal judgments are vague and unclear and cannot be described in detail for the most part. For instance, the decision maker can verbally state alternative "X" is strongly or weakly preferred over alternative "Y" but fail to give the exact ratio explaining this decision. Using a scale from 1 to 9 in pairwise comparison in ANP and AHP is simple but does not consider uncertainty in human judgment. Thus, the fuzzy

analytical network process is introduced to simulate uncertainty in the evaluation process, as human judgment is mostly uncertain and subjective. In view of the above, the developed model relies on the Fuzzy Analytic Network process to interpret the influential factors on a company's competitiveness.

The Fuzzy Analytic Network process is applied based on pairwise comparisons that are filled by experts. For example, the expert is asked to specify how important time is when compared against costs with respect to their effect on organizational performance. Another example is that the experts are asked to determine how important company resources are when compared against organizational structure with respect to their effect on organizational performance. In the developed FANP model, triangular fuzzy numbers were used to reflect the preferences of the experts towards the influential factors present in the pairwise comparison matrices. The Fuzzy preference programming (FPP) proposed by Milkhailov [89] is deployed to obtain the local weight from the fuzzy matrices. In this regard, the fuzzy preference programming algorithm comprises formulating a non-linear prioritization function that aims at maximizing the consistencies of the respondents in order to derive the local priorities of the influential factors such that zero and one are set as the lower and upper bounds, respectively. The unweighted supermatrix is generated capitalizing on the derived local relative importance weights. The weighted supermatrix is established by the values of the elements of the unweighted supermatrix by their relative clusters' weights. The limit supermatrix is obtained by raising the elements of the weighted supermatrix to a higher power until convergence, where all the columns' entries that correspond to any node have similar values. The limit supermatrix can be mathematically defined as per Equation (1) [90,91]:

$$M_L = \lim_{x \to \infty} {M_W}^c \tag{1}$$

where M_W and M_L stand for the weighted and limit supermatrices, respectively. c is the higher power to which the weighted supermatrix is raised to.

4.3. Basic Procedures of PROMETHEE II

The family of the PROMETHEE outranking algorithm was first introduced by Brans (1982) [92] to provide a partial ordering of a predefined set of alternatives. This algorithm was further extended to PROMETHEE II that was introduced by Brans and Vincke [93] in an attempt to establish the full ranking of a finite set of design alternatives. In the PROMETHEE II algorithm, a preference function is assigned with each design criterion. According to it, the degree of preference of alternative "a" over alternative "b" is determined. In the preference function, the difference in the evaluations of two alternatives is converted into a preference degree that falls between zero and one. There are several types of preference functions such as level criterion, V-shaped criterion, U-shaped criterion (Quasi), usual criterion, Gaussian criterion and V-shaped with indifference criterion (linear).

The preference function is usually defined using two parameters which are the preference threshold and indifference threshold. Preference threshold is the smallest deviation that is considered as decisive by the decision maker in determining the preference of an alternative over the other. Indifference threshold denotes the largest deviation that can be neglected by the decision maker. The value of the preference threshold is always greater than the indifference threshold's value [94,95]. Gaussian threshold is utilized in the Gaussian preference function only and it is usually set as an intermediate value that lies between the indifference threshold and preference threshold [96]. V-shaped preference function is assigned to all criteria because it is recommended for utilization by researchers in dealing with quantitative data in order to create a distinct variation between evaluations of alternatives [97–99]. The preference threshold value is usually set as 60% of the difference between the largest and smallest values of the performance scores of the respective performance criterion. In addition, the indifference threshold is set to be equal to 30% of the difference between the largest and smallest values [100,101].

The basic procedures of applying PROMETHEE II are presented in the following lines [102]:

The first procedure is to compute the differences between alternatives based on pair-wise comparisons as follows:

$$d_j(a,b) = g_j(a) - g_j(b) \tag{2}$$

where $d_j(a,b)$ represents the difference in performance evaluations between alternatives a and b with respect to attribute j.

The second procedure involves the application of preference function for each attribute based on its type and corresponding threshold as follows:

$$p_j(a,b) = H\left[d_j(a,b)\right] \tag{3}$$

where $p_j(a,b)$ denotes the preference of alternative a over alternative b with respect to the $j-th$ attribute represented as a function of $d_j(a,b)$.

The third procedure encompasses the computation of the global preference index of the alternatives a and b through the application of the weights of attributes obtained from the Shannon entropy algorithm. This is accomplished using the weighted sum of $p_j(a,b)$ of each attribute j as follows:

$$\pi(a,b) = \sum_{j=1}^{n} w_j \times p_j(a,b), \quad \forall\, a,b \ \in A \tag{4}$$

where $\pi(a,b)$ denotes the overall preference intensity of alternative a over alternative b with respect to all the attributes. A indicates the set of available alternatives. It is worth mentioning that $\pi(a,b) \simeq 0$ implies a weak global preference of alternative a over alternative b while $\pi(a,b) \simeq 1$ implies a strong global preference of alternative a over alternative b.

After the computation of $\pi(a,b)$ for all pair-wise comparisons, the positive and negative outranking flows for each alternative are computed using Equations (5) and (6), respectively:

$$ø^{+}(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a,x) \tag{5}$$

$$ø^{-}(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a,x) \tag{6}$$

where $ø^{+}(a)$ and $ø^{-}(a)$ represent the positive (leaving) and negative (entering) outranking flows of alternative a, respectively. $ø^{+}(a)$ measures how much alternative a outranks other alternatives. $ø^{-}(a)$ reflects how much alternative a is outranked by other alternatives. Higher values of $ø^{+}(a)$ and lower values of $ø^{-}(a)$ imply a better alternative. n denotes the number of possible scenarios, whereas each alternative a is compared against $n-1$ alternatives in the decision matrix.

The final procedure involves the computation of the net outranking flow to generate an overall ranking of alternatives using Equation (7):

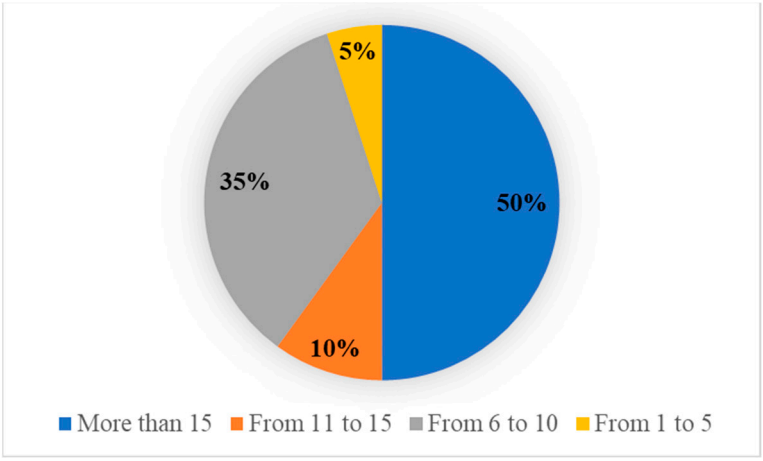
$$ø(a) = ø^{+}(a) - ø^{-}(a) \tag{7}$$

where $ø(a)$ refers to the net outflow. A higher value of $ø(a)$ implies a better alternative.

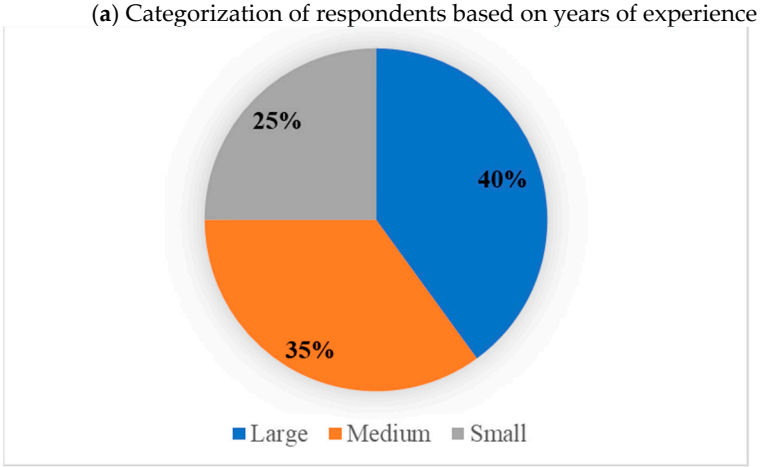
5. Results and Discussion

A questionnaire survey was developed to gather the preferences of the experts regarding the defined factors and their threshold values. The questionnaires were distributed to professionals in relevant fields of expertise in the construction industry and from different geographical locations. The questionnaire survey constituted three sections. In the first

section, the participants were asked about their background such as occupation, years of experience, the geographical area where they acquired most of their experience, their work categorization, construction type, their company's average work load and their company's size. The number of distributed questionnaires was 20, so that the targeted experts were from all over the globe and the interviews took place either online or in person. Data were analyzed to reach a better understanding of the gathered responses and make a better judgment over their accuracy. The construction type of the participant's expertise was categorized into three categories: infrastructure construction field experts, industrial construction field experts and construction real-estate experts. Their experience in the field was categorized into four sections, ranging between less than 5 years to more than 15 years and increasing by 5 years for each category. Figure 3a shows the number of participants with their respective years of experience. The highest percent of participants was located in the category of more than 15 years of experience with 50% of the total. Participants with between 11 and 15 years of experience represented 10% and between 6 and 10 years' experience represented 35% and finally, participants with between 1 and 5 years of experience represented 5% of the total.



(**a**) Categorization of respondents based on years of experience

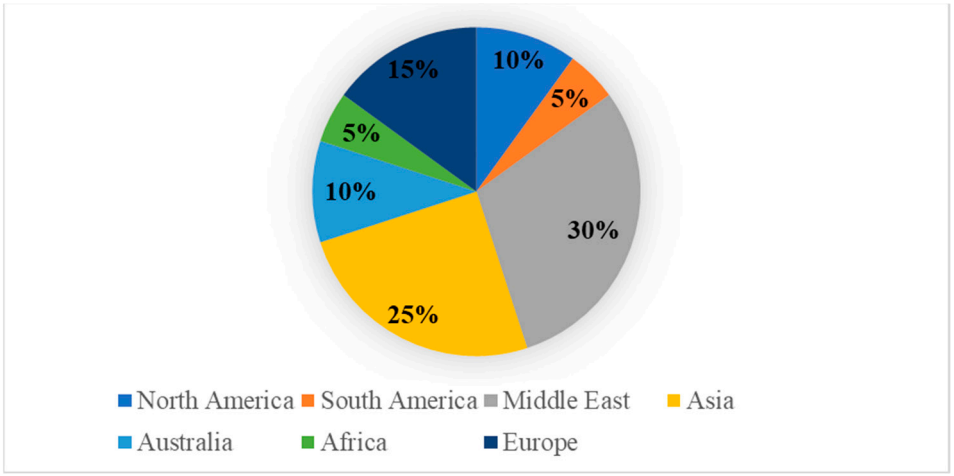


(**b**) Categorization of respondents based on company's size

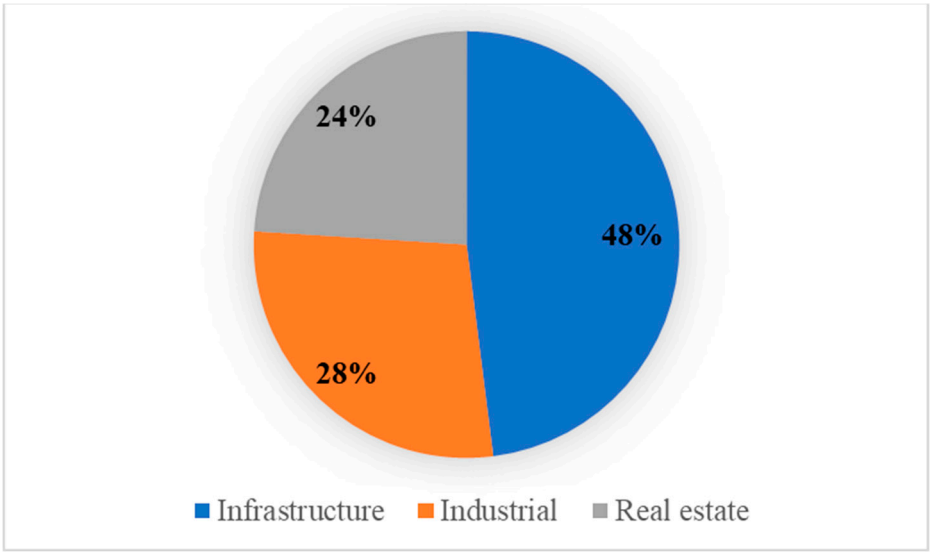
Figure 3. Categorization of respondents based on experts and company's size.

Figure 3b shows the three categories of the size of business namely: Small, Medium and Large with a percent of 25%, 35% and 40% of the participants in each category, respectively. Figure 4a depicts that the location of professionals was categorized into seven geographical regions: South America, North America, Africa, Middle East, Asia, Australia and Europe, with a percent of 10%, 5%, 30%, 25%, 10%, 5% and 15% of the participants in each region, respectively. Figure 4b illustrates the construction type of the participant's

expertise, categorized into three categories: infrastructure construction field experts, industrial construction field experts and construction real-estate experts, with 48%, 28% and 24% of the participants in each construction type, respectively.



(**a**) Categorization of respondents based on location



(**b**) Categorization of respondents based on construction type

Figure 4. Categorization of respondents based on location and construction type.

In the second section, the experts were guided to provide their opinion pertinent to the importance of the factors on the five-point linguistic scale that ranged from very high to very low. Very low represented the least effect and/or importance while very high represented the most effect and/or importance. The pairwise comparisons were conducted with regards to three levels. These levels comprised the pairwise comparison between all the pillars with respect to the overall performance, between all the factors with respect to the factors' categories and finally between the factors' categories with respect to each other. The first level of comparison involved comparing the importance of the category of "internal and non-financial factors" when compared against the category "financial factors" with respect to their effect on a company's competitiveness. An example of the second level was comparing the importance of the leverage ratio against the liquidity ratio with regards to their effect on the financial factors. In the third level, the experts were asked to specify their preference towards the importance of time when compared against costs with regards to their effect on quality. In the third section of the survey, the experts were asked

to provide minimum and maximum threshold values for each critical success factor and the average value was considered to facilitate the calculations.

The weights of the main categories (Wc), sub-categories (Ws) and factors affecting the construction company's competitiveness (Wf and Wf_g) are recorded in Table 1. The local and global weights of critical success factors are denoted as Wf and Wf_g, respectively. The final global weight was obtained by multiplying the local weight of the critical success factor times its corresponding sub-category times its affiliated main category. It can be interpreted that the external and financial categories are the most important having nearly equal weight while the internal category falls not too far behind them. In this regard, the weights of the external, financial and internal categories are 36%, 36% and 28%, respectively. With regards to the sub-categories, it is derived that organizational performance and project performance are the most preferred sub-categories with weights of 36.8% and 36.9%, respectively. In addition, innovation and development performance is found to be less important with a weight of 26.3%. With respect to the internal factors, the sub-categories of clients, industry conditions and relationships alongside regional economy, legislation and political aspects have an equal weight of 50%. In the internal factors category, it can be noticed that costs are the most important factor with a weight of 2.7% while technology abilities, adjusting one's abilities and human resources development and learning are the least important factors. The relative importance weightings of technology abilities, adjusting one's abilities and human resources development and learning are 1%. It can be also noticed that human knowledge, company resources, bidding and competitive strategy have nearly the same preference of 2.2%.

In the external factors category, it can be deduced that legislation and political aspects are the most important factor while clients are of lowest importance. The relative importance weights of legislation and political aspects and clients are 9% and 1.4%, respectively. At the level of financial factors category, it can be noticed that the growth ratio constitutes the highest preference followed by the profit margin ratio while the leverage ratio is the least preferred factor. In this context, the importance weights of growth ratio, profit margin ratio and leverage ratio are 9.3%, 9% and 5.1%, respectively. In the grand scheme of things, the growth ratio was found as the most preferred critical success factor followed by profit margin and legislation and political aspects. On the other hand, technology abilities, adjusting one's abilities and human resources development and learning are found as the least preferred critical success factors.

All the results from the calculations of the proposed model were discussed by experts and executives from the construction industry. The findings confirmed that new technologies in marketing and IT present significant impacts on the organization's performance and strategic management. As such, managers in the construction sector should place a special emphasis on some factors, such as organization performance, project performance, clients and environmental, innovation and organizational development. In addition, bidding plays an instrumental role in the process of enhancing a firm's competitiveness. On the other hand, factors' strength, such as debt and provision of finance, greatly undermine the importance of competitiveness. In addition, the role that an organization is supposed to play with respect to performance is also important and should focus on establishing long-term plans and strategies. Firm executives must ensure that more attention focuses on the need for projects to realize the expected value. It is a wide process that comprises co-creation initiatives with stakeholders, especially the clients.

Table 1. Weights of main categories, sub-categories and factors.

Main Categories	W_c	Sub-Categories	W_s	Factors	W_f	W_{f_g}
Internal Factors/Non-Financial	28%	Organization performance	36.8%	Human knowledge	21.2%	2.2%
				Company resources	21.2%	2.2%
				Bidding	21.2%	2.2%
				Competitive strategy	21.2%	2.2%
				Organization structure	15.2%	1.6%
		Project performance	36.9%	Time	14.3%	1.5%
				Costs	25.7%	2.7%
				Quality	20%	2.1%
				Other project management systems	20%	2.1%
				Marketing	20%	2.1%
		Innovation and development performance	26.3%	Technology abilities	13.9%	1%
				Adjusting one's ability	13.9%	1%
				Human resources development and learning	13.9%	1%
				Research and development ability	18.4%	1.4%
				Companies adaptation to new environments	20.6%	1.5%
External Factors/Non-Financial	36%	Clients, industry conditions and relationships	50%	Clients	19.4%	1.4%
				Industry conditions	33.3%	6.0%
				Relationships	23.8%	4.3%
		Regional economy, legislation and political aspects	50%	Economic Factors	42.9%	7.7%
				Legislation and political aspects	50.0%	9%
Financial factors	36%	Financial factors	100%	Profit margin ratio	50.0%	9%
				Activity ratio	20.0%	7.2%
				Leverage ratio	14.3%	5.1%
				Liquidity ratio	20%	7.2%
				Growth ratio	25.7%	9.3%

Five case studies were explored to investigate the capabilities of the developed competitiveness assessment model. The specifications of the five case studies are recorded in Table 2. The first company is a private firm that is based in Doha, Qatar and was founded in 2002. Some of its past performance portfolio includes a variety of international projects, such as housing, bridges, buildings and roads. The company's competitiveness record is exemplary in the field of enterprise management, suppliers and client relationships. The data about the company were provided by an executive representing the company with the assistance of three experts. The second company is a privately owned firm situated in Cairo, Egypt and started operations in 1982. Its experience record includes managing a variety of global construction projects, such as building, houses, roads and others. The data about the company were provided by two experts representing the company and who gauged its competitive ability. The third company is featured as the biggest construction firm in Canada that was founded in 1937. It has a variety of branches in the world and has participated in high profile projects.

The fourth company is a big private construction firm in Vietnam that was established in 1997. The company has vast experience in the sector of construction it deals with, comprising commercial, residential and infrastructure construction. The company's competitive record is exemplary in the field of enterprise management, suppliers and client relationships. The data about the company were provided by an executive representing the company. The fifth company is a firm that is based United Kingdom started in 1999. Its past performance portfolio includes a variety of international projects, such as roads and bridges. The company's competitive record is exemplary in the field of enterprise management, suppliers and client relationships. The data about the company were provided by an expert representing the company with the assistance of two other experts. Tables 2 and 3 show the output of the competitiveness index of each construction company. The competitiveness index is produced based on the net outranking flow of the PROMETHEE II algorithm.

It is worth mentioning that a higher competitiveness index implies a more competitive company. It can be evinced that the fifth company has the highest competitiveness followed by the first company while the fourth company is the least competitive company. In this context, the competitiveness indices of the fifth, first and fourth case studies are 8.23, 6.25 and 2.3, respectively.

Table 2. Description of the five case studies.

Case Study	Location	Establishment Year	Area of Expertise
Construction Company 1	Doha, Qatar	2002	Housing, bridges, buildings, and roads
Construction Company 2	Cairo, Egypt	1982	Buildings, houses and roads
Construction Company 3	Canada	1937	Residential and commercial, and infrastructure construction
Construction Company 4	Vietnam	1997	Commercial, residential and infrastructure construction
Construction Company 5	United Kingdom	1999	Roads and bridges

Table 3. Competitiveness index affiliated with each construction company.

Company	Competitiveness Index
Company 1	6.25
Company 2	5.5
Company 3	6.01
Company 4	2.3
Company 5	8.23

A sensitivity analysis was carried out to measure the influence of critical success factors. In this regard, the weights of the original criteria are adapted by −30%, −20%, −10%, 10%, 20% and 30%. Then, for each scenario, the weights of other attributes are computed. The output of the conducted sensitivity analysis is plotted in Figure 5. It can be evinced that "Liquidity Ratio" is one of the most sensitive factors with which construction companies should be highly concerned. On the other hand, introduces less variations in the competitiveness index. It is also observed that the factor of legislation and political aspects has considerable implication for the competitiveness of construction companies.

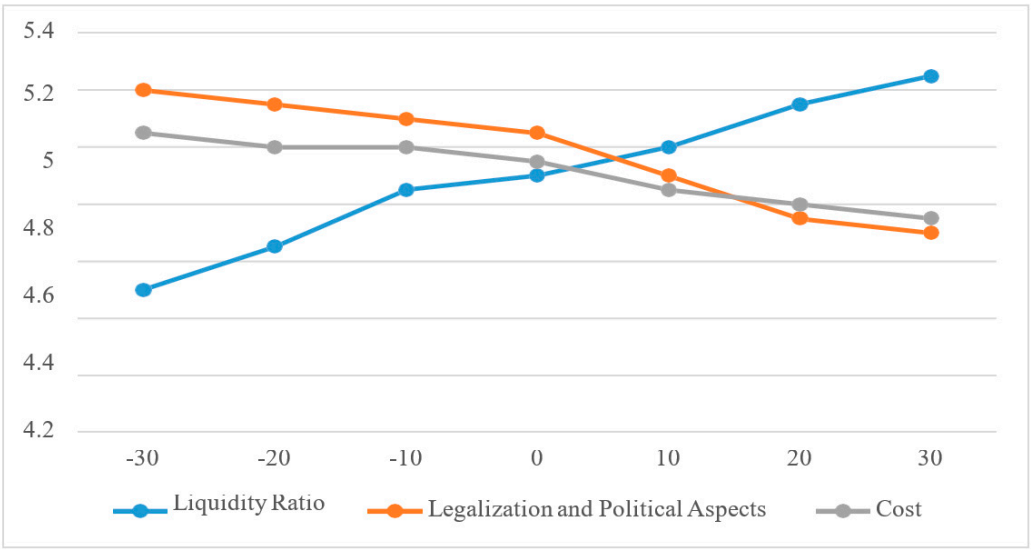


Figure 5. Output of the developed sensitivity analysis model.

6. Conclusions

The construction industry has become more complicated due to the continuous changes and challenges. As such, most construction firms are in a continual process to pursue higher level of competitiveness. Only companies with the capability to constantly modify their strategies can adapt effectively to sustain their operations and make more profits in the industry. However, most of the reported systems and provisions fail to monitor the level of competitiveness of construction companies. Thus, the main objective of the present research study is to design a competitiveness evaluation model for construction companies. The developed model identified a set of 26 critical success factors that control the level of competitiveness of construction firms. These factors were clustered into three main pillars that encompass non-financial external factors, non-financial internal factors and financial factors. The developed model exploited the use of fuzzy analytical process, based on fuzzy preference programming, in order to derive the relative importance weightings of critical success factors. Then, the developed model counted on PROMETHEE II to assess and rank construction firms based on their level of competitiveness. A sensitivity analysis was also undertaken to study the influence of critical success factors on companies' competitiveness. The results demonstrated that growth ratio, profit margin and legislation and political aspects are the most influential critical success factors on the competitiveness of construction firms, such that their importance weights were 9.3%, 9% and 9%, respectively. Five case studies of construction firms all over the globe were used to validate the developed model. It was interpreted that the fifth construction company attained the highest level of competitiveness while the fourth construction company was not competent. It can be argued that the developed model could assist employers in appraising and sorting the competitiveness of designated construction companies. Furthermore, companies can use it to set their markup values in the bidding process. However, this research paper has two main shortcomings. First, the developed model was constructed based on twenty questionnaires, whereas more responses would be required for the sake of obtaining more accurate results. Second, the developed model relied on PROMETHEE II merely for computing the competitiveness index of designated construction companies. In this context, more multi-criteria decision making algorithms such as complex proportional assessment, weighted aggregated sum product assessment (WASPAS) and operational competitiveness rating analysis (OCRA) could be experimented with, to obtain more robust competitiveness assessments. This current research can be extended in the future by incorporating more historical information to obtain more precise judgments and decisions. In addition, tailored competitiveness assessments can be constructed for designated construction companies based on their type and size.

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