An Evaluation Model for Competitiveness Index of Construction Companies

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ABSTRACT

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The construction sector continues to experience significant challenges brought by new techniques and technologies. 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 competitiveness edge. The existing literature shows that competitiveness approaches do not address current challenges. Thus, the primary goal for this research is to develop an evaluation model that would consider all essential factors in determining the competitiveness index of construction companies and so aid in their growth and development.

In this research three new pillars (3P) for competitiveness are introduced: (1) Non-Financial Internal Pillar; (2) Non-Financial External Pillar; and (3) Financial Pillar. This concept can help construction companies manage short-term and long-term strategic plans and goals. The 3P includes 6 categories and 26 factors incorporated and defined by the assessment model for measuring competitiveness. This research also rests upon a questionnaire that was sent globally to generate two sets of information which are the factors affiliated thresholds and the weights for the identified factors using the Fuzzy Analytical Network Process (FANP) which was required to reduce the uncertainty inherited from the

judgment of the respondents and the factors affiliated thresholds. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) technique was implemented using the weight of factors and their associated thresholds as an input. PROMETHEE was then used as a ranking technique to rank any given construction company by determining its competitiveness index.

The proposed evaluation model was validated through five cases studies that reveal its potential of illustrating detailed analysis with respect to the competitiveness ability of construction companies. A graphical user interface was developed for providing a competitiveness index for any construction company and rank companies relative to one another. It is anticipated that the proposed evaluation model can be used in decision making process by all parties involved in construction projects. Contractors can use the evaluation model in making better decisions regarding the markup values. Employers can also use the same model in the evaluation process of contractors.

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NOMENCLATURE

AHP: Analytical Hierarchy Process.

ANNs: Artificial Neural Networks.

ANP: Analytical Network Process.

BOA: Bisector of Area.

BSC: Balanced Scorecard.

C-CACS: Contractor Competitiveness Assessment and Communication

CCCIT: Construction Companies Competitiveness Index Tool.

CI: Competitiveness Index.

CICI: Competitiveness Index for the Construction Industry.

COA: Centroid of Area.

COA: Centroid of Area.

CPI: Cost Performance Index.

CSFs: Critical Success Factors.

CT: Critical Threshold.

FAHP: Fuzzy Analytical hierarchy Process.

FANP: Fuzzy Analytical Network Process.

FPP: Fuzzy Preference Programming.

GCR: Global Competitiveness Report.

GPF: Generalized Preference Function.

IMD: International Institute of Management Development.

KCCs: Key Competitive Criteria.

KCFs: Key Competitive Factors.

KPIs: Key Performance Indicators.

KSFs: Key Success Factors.

LOM: Largest of Maximum.

LSM: Least Squares Priority Method.

MAUT: Multi Attribute Utility Theory.

MCDA: Multi Criteria Decision Analysis Techniques.

MCDM: Multi Criteria Decision Making Techniques.

MOM: Mean of Maximum.

PROMETHEE: Preference Ranking Organization Method for Enrichment Evaluations.

QFD: Quality Function Deployment

RBV: Resource – Based View.

ROC: Rank Order Centroid.

RR: Rank Reciprocal Weight.

RS: Rank Sum.

SOM: Smallest of Maximum.

SPI: Schedule Performance Index.

SWOT: The Strengths, Weaknesses, Opportunities, and Threats.

TFN: Triangular Fuzzy Numbers.

TQM: Total Quality Management.

TT: Tolerance Threshold.

WCY: World Competitiveness Yearbook.

WEF: World Economic Forum.

3P: Three Pillars

4P: Four Pillars

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CHAPTER 1: INTRODUCTION

1.1 Overview

Efficient management and competitiveness 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 (Chinowsky, 2001). 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 advancements and few progress has been recorded. Globalization as well 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 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 (Abraham, 2000). Hence, companies with better resources management has advantage to compete in the global market and gain extra benefits.

Globalization enhances the level of competitiveness, challenging participants to equip themselves better in terms of innovative advantages to be able to stand the fierce market. For example contractors in certain countries such as China could have cheap labor and superior management skills (Barney, 2001). This could lead them to exploit opportunities on 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 competitiveness ability by re-thinking and re-evaluating competitiveness.

1.2 Problem Statement and Research Objectives

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 (Bassioni, 2005). According to current literature, no assessment models address the current problems affecting companies in this industry. Additionally, current competitiveness performance models do not provide a concrete and accurate assessment. This research aims to reduce 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. This objective is achieved by addressing the following:

- Study and identify the affecting factors for competitiveness.
- Reduce subjectivity and uncertainty in the evaluation process.
- Determine and develop a competitiveness index for construction companies.
- Develop an intuitive user interface for companies competitiveness index based on industry type and company size.

1.3 Research Methodology

The proposed model of competitiveness assessment considers limitations of previous works and addresses underlying challenges that are faced by construction companies. The proposed methodology that will guide this analysis in fulfilling the pre-highlighted objectives are provided in the following section.

1.3.1 Literature Review

In the literature review phase, factors that undermine or enhance competitiveness and provide a foundation for growth and development are studied and presented. The different models addressing competitiveness are also studied in this phase. One of these developed models examines a set of competitive theories related to Porter's competitiveness model informed by strategic management, the resource-based view model (RBV) (Bassioni, 2005). Another model introduced four pillars (4P); (1) Organization performance, (2) Project Performance, (3) Environment and client and (4) Innovation and development (Huang et al., 2010). These four pillars include several factors that undermine the competitiveness of companies in the construction sector.

1.3.2 Integration of the three pillars (3P) concept and the competitiveness Principles

Project and organization performance could fail to link the financial aspects and their effect on competitiveness of construction companies. Hence, the three pillars (1) Non-Financial Internal Pillar, (2) Non-Financial External Pillar and (3) Financial Pillar were used in this research to study the effect of different factors on a company's competitiveness. The 3P concept has the potential to support construction companies to manage short-term and long-term strategic plans and goals. The model of the 3P concept includes 6 categories and 26 factors incorporated and defined by the assessment model to gauge the competitiveness of construction firms.

1.3.3 Data Collection

In order to develop the proposed evaluation model, the different weights and thresholds of the different considered factors were determined via questionnaires. Experts in the construction industry were addressed to assess the relative importance of the different factors and their effect on competitiveness. The questionnaires gathered information pertaining to the relative importance of key factors and their associated thresholds, which were then processed using Fuzzy Analytic Network Process (FANP) and PROMETHEE.

1.3.4 Developing Competitiveness Evaluation Model

FANP was employed to calculate the weight of factors affecting competitiveness. The factors' weight and their affiliated thresholds are the main input for the MCDM technique known as the PROMETHEE, which ranks the construction companies based on their competitiveness ability. The proposed model developed relied on the factors proposed in the literature review and the opinions of experts.

1.4 Thesis Organization

The literature review in Chapter 2 presents an evaluation of some competitiveness models and theories, issues regarding competitiveness in the construction industry, and some models available for assessing the competitiveness ability of companies. The different MCDM techniques, including PROMETHEE and FANP as well as the strengths and shortcomings of current models are presented.

Chapter 3 explains the methodology adopted in this research. It is also backed by a review of the literature, the definition of factors and the collection of the data required to develop the proposed evaluation model. The different steps of developing the models are described. Chapter 4 describes data processing as to generate two main sets of information. The first set is the factors' relative weight and the second is their associated thresholds.

Chapter 5 details the process of generating the evaluation model for determining competitiveness. The model is developed using FANP to determine the factors relative weights. Factors' relative weights were considered the main input to PROMETHEE beside the threshold values, reaching to the construction company competitiveness index.

Chapter 6 presents a validation of the proposed model, there were a total of five case studies, used to examine the accuracy of the model of competitiveness index. The weights of the factors were based on data gathered from international companies in the construction industry with different sizes and industrial types in which PROMETHEE outcomes are analyzed.

Chapter 7 presents recommendations and conclusion. It also covers the research limitations and possible areas of enhancement. The section also presents the contributions that have been realized by the study and any enhancements recommended for future works.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

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, skills of labor and change in the environment conditions. Only companies with the capability to continuously modify their strategies can adapt effectively to sustain their operations and make more profits in the industry. 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 competitiveness ability of construction companies. Checking, measuring and improving competitiveness ability is the best method to maintain success (Flanagan, 2005).

2.2 Competitiveness of Construction Companies

Competitiveness can be described as “the capability of a company to adopt with structural changes” (Beck, 1990). Porter (2008) 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 in 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 (Ivancevich et al., 1997). Competitiveness is defined in 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 services and products which consumers can obtain from other competitors (World competitiveness yearbook, 2003).

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 (Ling and Gui, 2009). The initiative is conducted on an annual basis to measure the competitiveness nature of construction companies. The reports offered various definitions of competitiveness. They identified, calculated and surveyed factors of competitiveness at a national level.

For industries level, detailed analyses are conducted on industries. They also develop competitiveness theories concerning organizations, focusing solely on their competitiveness nature. This calls for a competitiveness 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 (2006), 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.

2.3 Theories of Competitiveness in Construction Industry

One theory that measures competitiveness in the construction industry is Porter's Competitive Theory, which studies how companies position themselves strategically for competition. Porter has developed systems to examine strategies for competitiveness that companies adopt and their connection to competitiveness abilities and advantages. The model includes forces that inform competition in industries, three generic competitive strategies, the diamond model, and the value chain (World Economic Forum, 2009). A concrete analysis of competitiveness requires an examination of both the internal and external factors in an integrated model. Yet, Porter's model lacks the internal mechanisms to convert the impact of undesirable external elements into internal capabilities. Figure 2.1 shows the different factors included in porter's model. The model studied the factors such as threat to new entrants and substitute products or service in addition to bargaining power of suppliers and buyers and how they could affect the rivalry among competitors.

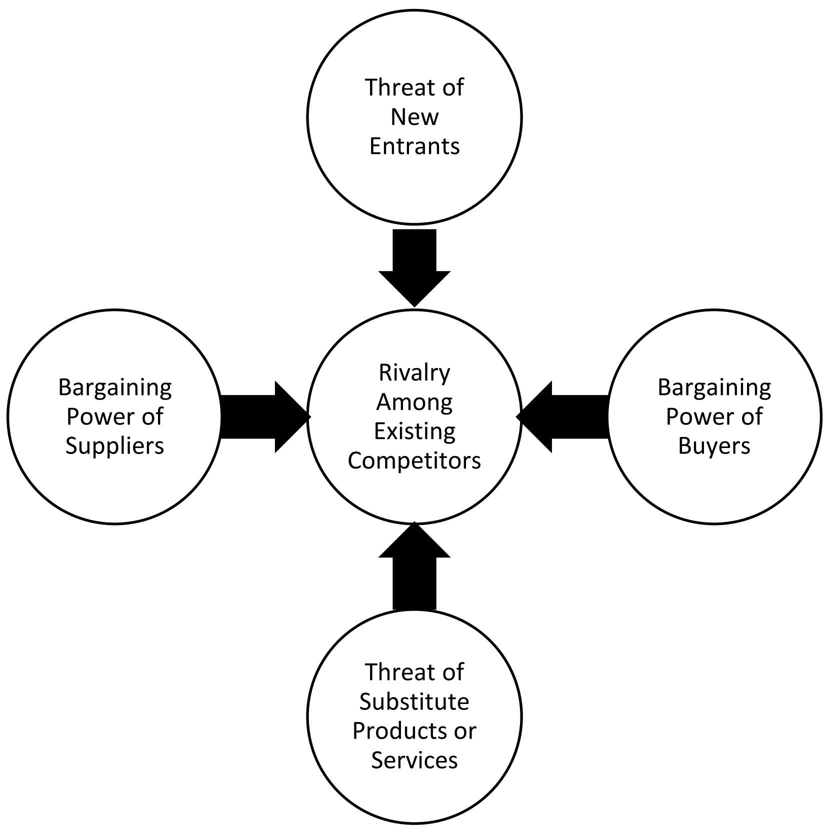


Figure 2.1: Forces Driving Industry Competition (Porter, 1980)

Core competitiveness is another key, a collective learning point in the majority of organizations coordinating a high number of diverse skills and integrating them into multiple technology streams. It is an involvement, a communication, and a deep commitment technique for coordinating works across different organizational boundaries (Lu, 2006). It emphasizes internal factors and resources at the disposal of any company while measuring its competitive ability. Based on strategic management, it defines the activities of various companies, especially regarding competitors. Its main advantages are that it provides consumers with various benefits, cannot be easily imitated by competitors, and offers leverage for numerous products on the market.

The balanced scorecard is one of the most useful techniques for determining and measuring company's performance. Applied in a number of business entities to manage success initiatives, it focuses on the financial structure of a company, its operational, developmental, and marketing functions. The balanced scorecard is helpful for measuring the success and competitiveness of construction companies. It is also useful for designing the vision and mission of an enterprise. Initial scorecards were able to achieve balance by encouraging business executives to select measures from three categories: customer, growth and learning, and internal business processes (Wong et al., 2000). Such a model would be useful for establishing a new conceptual framework for managing performance in the construction industry. Though the balanced scorecard measures performance management in the construction sector, it does not necessarily consider some distinct features of construction companies nor their operations and structure of processes. It places less emphasis on the construction sector, where project metrics such as the relationship between management and suppliers deserves consideration. Figure 2.2 shows the balanced scoreboard as per (Kaplan and Norton, 1992) and the different factors included affecting the vision and strategy of a company's competitiveness as per this theory.

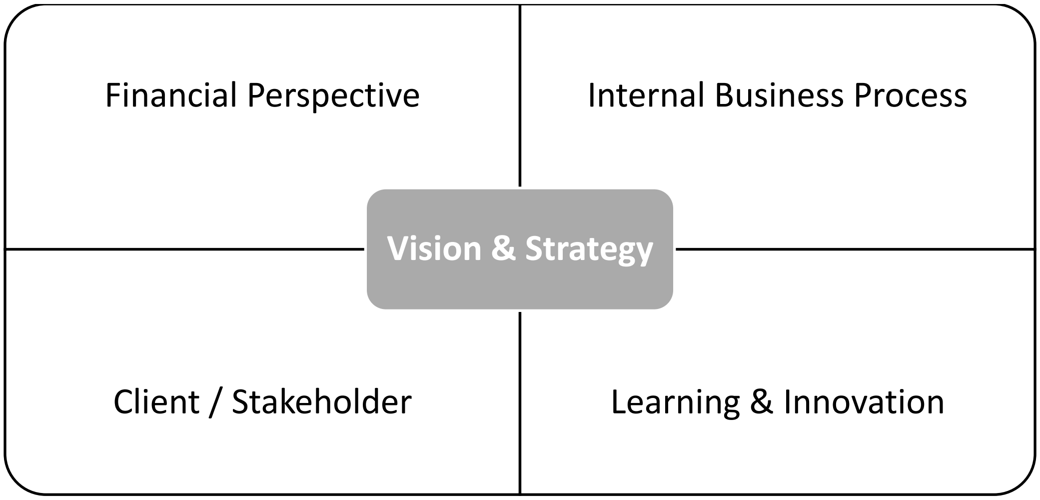


Figure 2.2: Balanced Scorecard (Kaplan and Norton, 1992)

The other model is the Resource-based view (RBV) that determines the strategic resources that can be acquired for a given company. It assumes that the competitiveness of a company in the construction sector is largely determined by the nature of its available resources. This model aims to enhance firm competitiveness by converting short-term resources into sustainable ones. What is more, competitive advantage provides that the resources have to be varied in nature and positioned in such a way that the rivals cannot access/imitate them easily (Mazri, 2005). For an organization to derive a sense of competitive advantage from the resource matrix, it is critical for the resources to be heterogeneous and mobile in nature. They are supposed to reflect four attributes: rarity, value, hard to imitate, and have no substitutes. In addition, RBV is about developing a fit in the context of the external market. Figure 2.3 shows the different phases in the RBV and the different attributes in this model. As shown in the figure the model can be divided into two phases namely competitive advantage and sustainable phase.

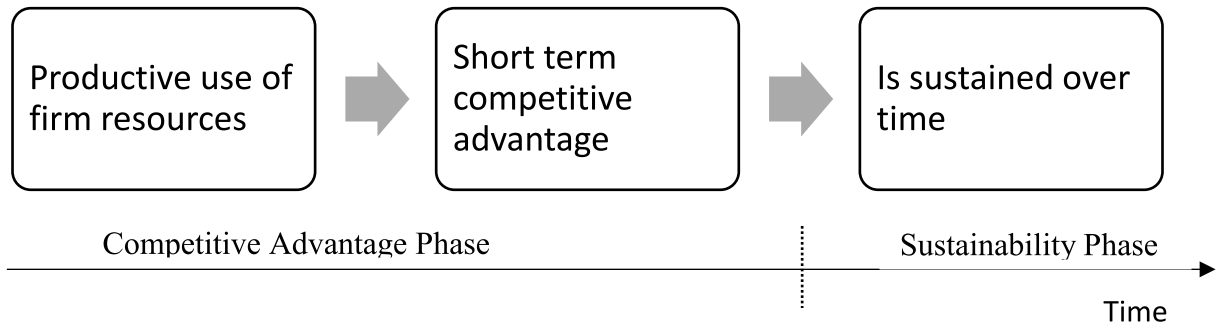


Figure 2.3: Resource Based View (Barney, 1991)

2.4 Factors Promoting Competitiveness in the Construction Sector

Critical success factors (CSF) feature as a business supporter model that ensures organizations are able to achieve their goals and missions. They are activities or critical factors required to guarantee the success of a business. CSFs were assessed and modelled in various construction organizations based on data from surveys in several companies in different countries such as Egypt and Canada (Mazri, 2005). Common CSF for construction firms were determined by a series of studies. Ngowi (2001) adopted a model combining the latest strategic management theories: the seven guiding principles that support strategic management in the field of civil engineering. Momaya & Selby (1998) added another dimension that included critical information from organizations with double knowledge domains.

CSFs identify and define the main elements required for a firm to become successful in any industry. Researchers have understood the CSF model as an approach that has the potential to affect the competitive capacity of companies within a strategic group or an industry. Ngowi (2001) categorically stated that some of these factors are determined by the technological and economical attributes of industries, including a firm’s competitive power that enables it to apply strategic variables, focus on the quality of products, and command organizational competency in the wake of realizing more value for customers.

Another useful analysis framework, SWOT (strengths, weaknesses, opportunities, and threats), is used to evaluate the internal and external environments of organizations. The first two elements (the strengths and weaknesses) aid business executives to understand their internal environment and make effective recommendations. The last two (opportunities and threats) study the external environment to make the most rational steps. Each element makes it possible for companies to make beneficial initiatives or become aware of losses resulting from making the wrong decisions (that do not align with demands from the internal and external environments). This model can be used to improve the competitiveness of firms in the construction industry. The last two provisions of the model assess the external environment, focusing on the threats that the business faces and the opportunities that it can capitalize on as a way of countering them (the threats). Table 2.1 summarizes the different elements considered in the SWOT model.

Table 2-1: SWOT Analysis (Ling et al., 2009)

	Helpful	Harmful
Internal Origin	Strengths	Weaknesses
External Origin	Opportunities	Threats

Key performance indicators (KPI) feature as one of the widely used frameworks for measuring performance in the United Kingdom which has been widely used in other countries. According to Ngowi (2001), KPI indicators measure the performance of organizations and projects in the entire construction industry. By using KPI, business executives can determine their short-term performance only, excluding long-term performance, a key ingredient in firm competitiveness. Various techniques shall be conducted to decrease the gap between performance measurement and apply conventional measuring techniques, as well as better understand how to use performance measurement metrics successfully.

2.4.1 Classifying Competitiveness Factors

In this section, previous research addressing the competitiveness factors and how the different attempts to classify these factors are presented. In this section, one widely used concept which is the 4P (Huang et al., 2010) used to define the factors affecting the companies' competitiveness index is introduced. Additionally, the different criteria for the different pillars studied in previous research studies are also discussed. The classical triangle framework to manage projects (time, quality, and cost) has limitations when it comes to addressing current developments. It does not consider the effect of changes brought about by technology, by changes in the market, and by innovative improvements. To address some challenges in the construction market, four pillars were proposed: client and environment, development and innovation, project performance, and organization performance.

2.4.1.1. Four Pillars (4Ps) Concept in Construction Industry

Four main pillars in the construction industry can be applied to address the limitations and challenges in most literature: project performance, organization performance, client relationship, and the environment. These four elements are further categorized into 21 Key Competitive Factors (KCFs) and 80 Key Competitive Criteria (KCC). Communication, technological advancements in Information Technology (IT), and globalization are some of the factors that affect the performance of companies in the construction sector. Imperatively, innovation has emerged as a fundamental tool in the course of acquiring competitive advantage in an environment developing gradually.

Communication, technology, and management functions affect the effectiveness of procedures in project execution. They are a way for stakeholders to develop a number of execution plans. In the contemporary business environment, company executives can monitor the exact value of cost performance index (CPI), Schedule Performance Index (SPI), and cost of each construction project through smartphones, and internet despite distant locations (Ofori, 1994). They can instantly align the plans of an organization with incoming information. Staff members can stay updated on information from the organization through their mobile phone and internet communication. This makes it possible for employees to be connected directly to the company, placing them in a position to make quick decisions regarding problems. The role that Human Resources plays in an organization is also vital since clients, owners, and staff members are connected and informed on a global scale. The client is able to communicate directly with the managers of a project and also participate in decision making processes. The possibility to choose suppliers, materials, client tasks, and other items has become more advanced, and engenders higher responsibilities.

Increased knowledge can make the workplace environment evolve from skill-based to knowledge-based (Ofori, 1994). This means that both staff and their executives are supposed to study construction techniques to generate new knowledge daily. According to (Ofori, 2003), the policy and structure of organizations should be adjusted to align with new technology, environments, and knowledge (Orozco, 2014). Staff members can be made more aware of the strategy and associated vision of the firm, and of the detailed problems that the project brings about (Porter, 2008). This also means they are enabled to share visions, goals, missions, and strategies for their respective organizations.

2.4.1.1.1. Organization Performance

According to the Porter model, the human resources is key to supporting the activities and operations of an organization. The majority of competitive theories consider the knowledge base of the personnel an important competitiveness asset. A few studies have applied the methods of competitiveness by focusing on the productivity of a firm's employees. Since employees form the critical backbone to a company's overall success. When staff members are productive and innovative, the organization aligns for both short-term and long-term success. Knowledge and human capital are considered a critical KCF and their corresponding KCCs are summarized in Table 2.2.

Financial resources can be considered as a major resource for an organization. It comes in many forms, such as enterprise cash-flow, the ability to raise equity, cash equivalent, and the firm's borrowing capacity (Porter, 2008). A company's level of profit demonstrates its business effectiveness on the market. An organization with higher profits, higher income, and lower debt is considered a strong competitor. Profits and finance are some of the KCFs of construction firms. To evaluate profitability, income, and debt, sufficient financial analysis ratio is required. This computation uses KFCs (Table 2.2) to measuring competitive strategy in construction firms using competitive bidding to achieve the best value and various support tools for decision making (Porter, 1985). In recent decades, managers and executives alike have experienced shifts to a "multi-criteria selection" from a "lowest-price-win."

The organizational structure is an example of both KCC and KCF as shown in Table 2.2. Companies are supposed to develop clear duties and divisions to create functional departments. Such hierarchy levels are effective for fostering good relationships among clients, suppliers and stakeholders. The leader's role is to bring team members together towards goal attainment. Moreover, in the context of globalization, executives are supposed to be aware of the international standing of their respective firms.

In addition to competitiveness factors, managers should develop an awareness of the resources available, such as equipment or the culture of the organization. Such factors are valuable because they directly inform the competitiveness of an organization. The number of years in operation reveals the level of experience that a company possesses and is a good way of determining its past competitiveness capacity. Based on this perspective, the resources of an organization are a critical KCF and KCC elements.

2.4.1.1.2. Project Performance

Construction managers are asked to deal with projects as if they are one part of the construction company involving numerous departments and projects, as opposed to an isolated case. To realize sustainable competitiveness, construction company managers should shift attention from a single project to a level of organizational strategies, aligning simultaneously all goals of a project with the general strategies of companies. Project-oriented management could be used to respect project demands, such as time, quality, and cost issues. For long-term success, less management attention is paid to areas considering critical management issues. As competition levels increase in both quantity and quality, firms in the construction industry should emphasize long-term ambitions, benefits, and strategies.

As a result of increased competition on the market, construction companies must combine a series of projects to increase revenue. Professional engineers and skilled labor must be treated as an important asset in order to develop a feasible competition strategy. Advancements in construction technology and knowledge are supposed to be reinforced by more education, strategy management, and cooperation at the company level. Consequently, construction companies face new challenges that should push them to shift their perspective from organization performance to project performance. So far, time, quality, and costs are regarded as some of the most important factors to project managers. Numerous articles have highlighted the importance of these factors pertaining to project performance. In this light, costs, time, and quality are considered as KCC and KFCs as shown in Table 2.2. Aside from the three factors, there are other factors in construction management that are vital for analyzing firm competitiveness as described in details in Table 2.2.

2.4.1.1.3. Environment and Client

Given increases in competitive contractors, the client can choose among a wide selection of contractors. Consequently, contractors increase quality level, shorten delivery deadlines, and lower the bidding cost. The rampant competition between contractors has provided the client with sufficient leverage in selecting the most feasible bid. Parallel to these factors, advancements in the field of communication technology make it possible for the client to monitor the products with suppliers closely and efficiently. As KCCs and KCFs matrices shown in Table 2.2, supplier and client environments are considered key elements in the concept of the 4Ps.

2.4.1.1.4. Innovation and Development

To sustain competitiveness, construction firms are required to satisfy client demands regarding products and services. Table 2.2 describes the client satisfaction which is considered as a KCF and KCC provision. Research and Development (R&D) ensures that organizations are equipped with the resources that enhance their core competitiveness and establish new tools required to address latent challenges. R&D implementation features as a KCF and KCC as shown in Table 2.2. To innovate and develop, organizations are expected to invest in building stronger and reliable human capital, recruit staff, and attract labor. Learning and the development of human resource are KCCs and KCFs as shown in Table 2.2.

Table 2-2: Competitiveness Factors (Huang et al., 2010)

Pillar	Key Competitive Factors (KCF)	Key Competitive Criteria (KCC)	Pillar	Key Competitive Factors (KCF)	Key Competitive Criteria (KCC)
1.Organization Performance	1.1 Human and Knowledge	1.1.1 Employee productivity 1.1.2 Number of full time employees 1.1.3 Number of staff bachelor's degrees 1.1.4 Number of employees with more than five years of experience 1.1.5 Organization's knowledge resources & quality of staff 1.1.6 Organization's effective use of people & knowledge resources	3. Environment & Client	3.1 Client Satisfaction	3.1.1 Client's satisfaction with (the value for money on delivered Products) 3.1.2 Client's satisfaction with (the value for money on delivered services 3.1.3 Client's satisfaction with specified criteria
	1.2 Finance and profit	1.2.1 Profit Ratio: Net profit margin = Net income / total sales 1.2.2 Activity Ratio: total assets turnover = sales / total assets 1.2.3 Leverage ratio: Debt to total assets = Total debt / Total assets 1.2.4 Liquidity Ratio: Quick ratio = Current Assets less inventories / Current liabilities		3.2 Company Social and industry condition	3.2.1 Social conditions 3.2.2 Construction industry conditions
	1.3 Other Company resources	1.3.1 Equipment availability (%) 1.3.2 Effective use of organization's other resources 1.3.3 Number of years in business 1.3.4 Value of projects completed in the past three years ($) 1.3.5 Organization Culture		3.3 Client and Supplier environment	3.3.1 Client environment 3.3.2 Organization's client and supplier awareness 3.3.3 Supplier environment
	1.4 Bidding	1.4.1 Success rate (%) of bidding over past three years 1.4.2 Effectiveness of organization's bidding strategy 1.4.3 Sum of contract over past three years ($) 1.4.4 Experience for bidding & availability of resources and professional for bidding		3.4 Relationship	3.4.1 Relationship with client or owners 3.4.2 Relationship with government departments & with public 3.4.3 Relationship with subcontractors or suppliers & with designers and consultants
	1.5 Competitive strategy	1.5.1 Strategy implantation 1.5.2 Matching strategy to an organization's situation 1.5.3 Strategic awareness & clear vision mission and goals	4. Innovation & Development	4.1 Technology ability	4.1.1 IT application 4.1.2 Technological innovation ability & technical application 4.1.3 Investment in technological Innovation 4.1.4 Ratio of technological contribution
	1.6 Organization structure	1.6.1 Suitability of company structure 1.6.2 Business efficiency 1.6.3 Leaders' personality and capability 1.6.4 Use of international aspect (ISO) 1.6.5 Organization communications		4.2 Strategy to develop	4.2.1 Strategy implementation 4.2.2 Strategic awareness & clear vision, mission and goals
2. Project Performance	2.1 Time	2.1.1 Schedule Performance index (SPI) 2.1.2 Effectiveness of time management 2.1.3 Construction delays		4.3 Human resources development & learning	4.3.1 Employee salary 4.3.2 human resources development strategy 4.3.3 Effectiveness of employee enhancements, training and education 4.3.4 Money investments per one employee (for enhancements training and education) per year 4.3.5 Labor attractiveness, work conditions, wage level, employee motivation and job satisfaction
	2.2 Cost	2.2.1 Cost performance index CPI 2.2.2 Effectiveness of cost management		4.4 Research and development ability	4.4.1 Ratio of R&D contribution per total revenue 4.4.2 Investment on R&D 4.4.3 Effectiveness of research and development ability
	2.3 Quality	2.3.1 Defects (at the time of handover) 2.3.2 Total quality accidents per year ($) 2.3.3 Effectiveness of quality management		4.5 Adjust oneself ability	4.5.1 Creative ability & flexible ability of organization 4.5.2 Business coverage differentiation ability (per year) 4.5.3 Feedback evaluation ability
	2.4 Other project management issues	2.4.1 Health and safety reportable accidents 2.4.2 Health and safety lost time accidents 2.4.3 Risk management 2.4.4 Site management 2.4.5 Contract management 2.4.6 Dispute resolving skills 2.4.7 Management claims 2.4.8 Logistic and supply chain management 2.4.9 Environment management		4.6 Marketing	4.6.1 New orders received % 4.6.2 Business coverage type of projects 4.6.3 Business coverage type pf regions 4.6.4 Company experience in the market 4.6.5 Market research, planning and publicity 4.6.6 Marketing information

2.4.2 Research Studies Addressing Competitiveness

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. As a result of increased interest in competitiveness by researchers in different sectors, the concept carries various definitions. Though these definitions appear simple in concept and measurement, they do not lend themselves easily to the construction sector given its heterogeneity (Wu & Chang, 2008). While Wethyavivorn (2009) asserts no exact definition of competitiveness exists in literature, some common competition approaches can help define contractor competitiveness. While some maintain it is the ability of a company to attain high success levels in construction projects, others provide companies with reduced lead time, increased quality of outcomes, and reduced production costs

Affecting factors help inform companies' short-term and long-term competitiveness and also ensure they put up superior performances at all time. Despite its widespread use, no consensus exists concerning the definition of the capacity of competition for construction companies. The following definitions provide an enhanced understanding of competitiveness as a whole. The concept is more powerful than classical economic indicators, such as profitability, productivity, or market share; it is linked to achieving objectives related to the competitors performance; and is translated differently by various people. It does not just reflect historical performance, but makes it possible for one to perceive potential. It is supposed to satisfy the personnel’s and clients’ needs. It strives for superior quality and continuous improvement. It is linked to innovation and productivity. In short, competitiveness is connected to having better capabilities and abilities relative to competitors, considering past results, as well as future perceptions of a potential construction firm.

Competitiveness in the field of construction has been analyzed on different levels, including industry, country, project, and company. Two main variable types, the factors affecting the competitiveness ability of a company and indexes measuring various aspects, were identified. These are also known as results and cover competitiveness, including performance projects, profitability, client satisfaction, and market share. Competitive factors can be further divided into external and internal capacities. The latter include elements management inside a company (e.g. training, leadership, and innovation). External factors are induced from outside the company and management has limited control over (e.g. number of competitors on the market, government rules and regulations, public investment, interest rates, and others). These factors shape the environment companies operate in, creating a different atmosphere of competition for each country or industry.

2.4.2.1 Indexes, Factors, and Models for Competitiveness

A comprehensive list was developed from relevant indexes and factors affecting competiveness by Francisco et al. (2014). It resulted in a final set of 11 external factors, 58 internal ones (further grouped into seven clusters), and 29 indexes (further divided into nine categories). The conceptual model related to interrelationships and competitiveness relevant to construction companies included these factors and indexes. Some interactions between indexes and internal factors have undergone empirical analysis, while others were based on theoretical assumptions. Feasible hypothetical relationships require re-creation to generate empirical analysis. In earlier sections of this research, practitioners' experiences in the selected market were considered as a way of reducing the number of indexes and factors to be analyzed in the model. This approach is considered effective when handling qualitative elements and has been applied in similar surveys. Researchers developed questionnaires for collecting qualitative data in the Chilean construction sector, where the study's provisions and findings were applied. The study featured 44 senior executives from general construction firms who gave interviews.

Executives participating in this research represented high-level managers from some of the largest companies in the construction market in Chile. Though the survey population was relatively small, the questionnaires featured in the study were merely a filter and validation of the review findings of literature. Given the similarity of responses, no additional responses were needed. The validation and research interviews revealed about 41 factors labelled by experts as some of the most relevant factors concerning competitiveness in construction companies, with special focus on Chile. Table 2.3 provides the abbreviations for reference in both the analysis and developed model (Francisco et al., 2014).

Table 2-3: Most Relevant Competitiveness Factors and Indexes for Chilean Contracting Companies (Francisco et al., 2014).

INTERNAL FACTORS	
	STRATEGIC MANAGEMENT
LEAD	Leadership
IMAGE	Image and reputation
	PROJECT MANAGEMENT
CONMM	Contract management
HSMM	Health and safety management system
	HUMAN RESOURCES MANAGEMENT
TEAMW	Team work
TRNG	Training
INCEN	Incentive and rewarding system
MSYS	Personnel engagement and motivation system
	INNOVATION, R&D. AND TECHNICAL/ TECHNOLOGY FACTORS
TECH	Technical abilities
PRTECH	Technology applied to projects
INNOV	Innovation (products, services, or inner processes)
CNSTCA	Construction plant capacity
	FINANCIAL CAPACITY
FINST	Healthy and stable financial status
FINCA	Financing capacity
	INSTITUTIONAL AND BUSINESS RELATIONSHIPS
CLREL	Relationship and alliances with clients
SUPPR	Relationship and alliances with suppliers
	BIDDING FACTORS
EXPER	Company experience
PRICC	Price competitiveness

EXTERNAL FACTORS	
CMPTS	Number of competitors
FGNCO	Foreign companies' presence
LABSH	Shortage of qualify labour
SUBSH	Shortage of qualify subcontractors

INDEXES	
	FINANCIAL INDEXES
PROF	Profit margin
LIQU	Cash flow / Liquidity
ROE	Productivity of investments (ROE)
PROD	NON-FINANCIAL PRODUCTIVITY
CLSAT	CLIENT SATISFACTION
MKTSH	MARKET SHARE
SOCSAT	SOCIETY SATISFACTION
BIDEF	BIDDING EFFECTIVENESS
	FUTURE ABILITIES
COSRE	Cost reduction abilities
PRTECH	Cutting edge technology applied to projects (repeated)
ADTECH	Cutting edge technology applied to administrative processes
	PERSONNEL SATISFACTION
MRES	Personnel motivation
PDEVT	Career prospect and employee development
WENV	Work environment
	PROJECT PERFORMANCE
COST	Cost
QUAL	Quality
TIME	Time
HSRES	Health and safety

To empirically determine a company's competitiveness, the University of Pecs developed the respective model to generate the competitiveness index. The Schmuck method is commonly applied in Hungary, though it is insufficient for reflecting the numerous aspects that determine the competitiveness of a company, especially those in the construction sector that are more interested in time, cost, and quality. Truong-Van (2008) presented an orderly process that can be used to design a competitive strategy for construction companies. The methodology for strategic planning in this model comprised four main stages which were: examine the company's mission; survey the business environment; assess the main resources at its disposal of a firm; develop strategy. Founded on Porter’s theory, the model assessed differentiation, cost, leadership, and focus (Porter, 1980).

Porter’s theory explored models that inform competitiveness stability and positioning with respect to mode (innovation, timing, cost, and quality). The study in which the theory was introduced illustrated that construction companies are more likely to follow their strategies consistently while remaining flexible to any changes that could affect their operations. In addition to Korkmazet exploration model of competitive positioning, Yang et al. (2015) used organizational ecology to analyse a proper competitiveness position from an environmental perspective. Niche's width theory and resource partitioning theory were used in the organizational ecology analysis (Yang et al, 2015).

Tan (2009) introduced an effective model that can help assess competitiveness in construction companies. This research studied revealed 10 CSFs 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 (Porter, 2008).

Based on the field research and analysis, Chinowsky recommended that the best strategic management segments are market awareness and technology. Wang et al. (2006) undertook a survey on construction companies' competitiveness in various countries, including Egypt and Canada. Using Neural Network Training and Artificial Neural Network (ANNs), the study resulted in nine Critical Success Factors (CSFs) (Schrettle, 2014). These CSFs included: clear goals, mission, and vision; knowledge availability; evaluation of feedback; organizational structures; political conditions; business experience; research and development (R&D); competitive strategy; and employee culture.

In another study, Oz (2001) identified CSFs and Total Quality Management (TQM) for construction companies (Powell, 2008). He confirmed ten management CSFs executives should focus on. These CSFs were: quality organizational culture; commitment of the top management; quality design management; process management; training and education; involvement and empowerment; customer satisfaction; information analysis; and supplier quality management. Porter (2015) synthesized the strategies forwarded by Porter and others. He adopted their inconsistencies and consistencies, including Porter's Five Forces model and the concepts of value chain in the construction industry (Schrettle, 2014). He highlighted that master's programs should be more advanced as opposed to merely focusing on a construction project at the management level (Powell, 2008).

2.5 Models Developed to Evaluate Companies' Competitiveness

Warsawski (1996) developed an orderly process to determine competitive strategies using a four-step methodology for strategic planning that examines the mission statement and analyses 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 (2001) 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.

Another similar study (Arslan and Kivrak, 2008) collected qualitative data from 40 Turkish companies to explore some of the CSFs that determine their success. 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. The study stressed on the values of learning since construction is an enterprise founded on technology and business innovation is one aspect that can make a business remain competitive (Oz, 2001).

A study conducted by Rice University Building Institute developed 12 strategies for driving corporate success in the 21st century. The study considered the category ownership, value, vision, marketing, breakthrough, competitive intelligence, high-impact, human capital and customer intelligence, a culture based on continuous improvement, alliance building, and association with high-influential people. The competitiveness guided by synthesis of various theories proposed new methods. One of them was introduced by Lu, 2006. In the latter study the author came up with a model combining Porter's competitive model, resource-based view, and core competencies. Lu applied the principles and provisions of all these models to the Chinese construction industry, where he analyzed 33 CSFs and established a measurement index to measure competitiveness.

Lu maintained that a predetermined index is necessary for measuring competitiveness in Chinese companies. He equally stated that the competitiveness of contractors is derived from three generic sources (value activities, competitive strategy, and resources). When assessing contractor competitiveness, the company's nature and area of operation need to be considered. To design this index of competitiveness, Lu used weighted summation along with a system of information technology and contractor competitiveness assessment and communication (C-CACS) (Randy, 2001). All these elements were applied in index calculations to offer a sense of competitive abilities contractors should focus on.

The previous study determined that competitiveness is a business function that promotes sustainable growth and development. It cannot undergo proper analysis without evaluation at various levels (industrial, national, or firm level). Porter’s strategy and advantage model, as well as the core competencies and the resource-based view are highly effective for explaining competitiveness in construction enterprises. Assessing this kind of competitiveness is one major way for understanding sustainability in construction. The designed index was meant to determine contractor competitiveness (only) using CSFs (Schmuck, 2008). This is somewhat inadequate since the majority of elements are not CSFs but more factors that influence the success of construction firms. This model was customized according to the Chinese construction sector, and is not applicable in other settings.

2.6 Techniques Used in Evaluating Competitiveness of Construction Companies

Many recent studies have used different MCDA tools, Fuzzy set methods, artificial and neural network methods. Due to the uncertainties accompanying identifying the different factors affecting the construction industry, techniques in collaboration with fuzzy sets are used. For instance ANP could be used to determine the relative importance of these factors, however it doesn’t take into consideration the uncertainties inherited from human judgement and subjectivity. Hence, introducing fuzzy to ANP could be considered as an enhancement for such technique in this context. Additionally, techniques that are used to aggregate or rank the different criteria under study were also used in the previously developed model. This research uses Fuzzy Analytical Network Process (FANP) and Preference ranking organization method of enrichment evaluation (PROMETHEE). In the following section, an explanation for the different techniques is presented.

2.7 Multicriteria Decision Analysis Techniques (MCDA)

Belton and Stewart 2002 stated that there are two philosophies of MCDA and distinguished those philosophies into North American and European schools (Shurchuluu, 2002). The education institution situated in North America considers that those who make decisions possess sufficient information and understanding concerning the utility scores and weight of a criteria. Multi Attribute Utility Theory (MAUT), Analytical Network Process (ANP) and Analytical Hierarchy Process (AHP) are examples of innovations realized by this school (Sha, 2008). The European school considers the decision maker does not have sufficient information about preferences. PROMETHEE features as one of the well-known techniques used within the institution. Figure 2.4 illustrates the different categories and MCDA methods.

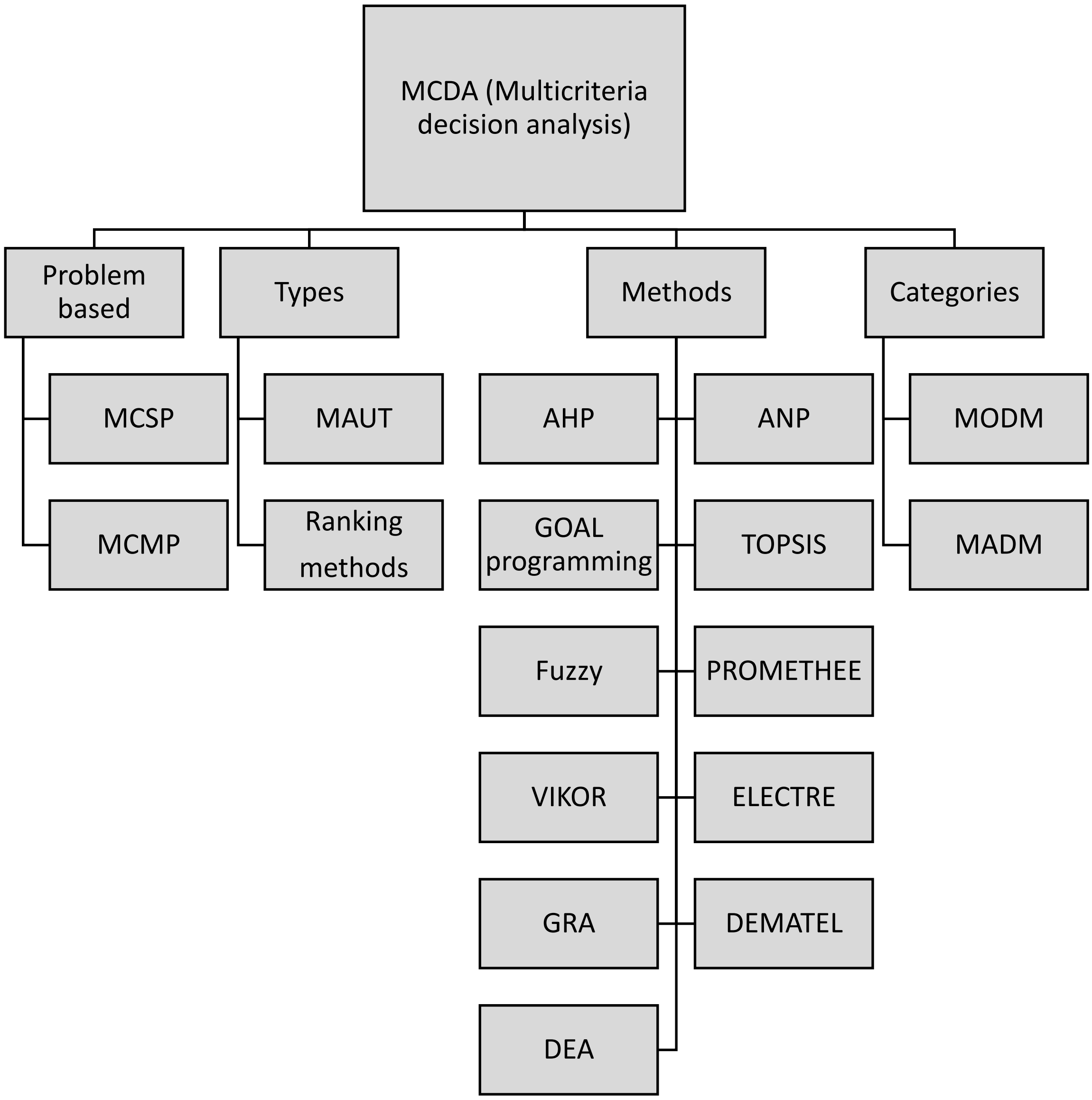


Figure 2-4: Multi-Criteria Decision Analysis Techniques

2.7.1 Analytical Network Process (ANP)

Multi Criteria Decision Making (MCDM) methods help decision makers and technical experts to determine the optimum strategic choice. Saaty (1980) developed a multi-criteria decision support methodology, analytical hierarchy process (AHP), which belongs to the North American School. Saaty (2001) presented ANP as an extension to overcome AHP limitations by considering interdependencies between the criteria. ANP output is relative importance of the criteria based on experts' opinions.

These opinions are presented in a pairwise comparison to show the relative effect of one of two elements over the other. Garuti and Sandoval (2005) stated that ANP can clear all relationships among variables and bring the model closer to reality. Pairwise comparison provides more precision that helps direct attention to one connection at a time. The real problem of ANP is that it needs a lot of effort to consider all interdependencies between the criteria while building the hierarchy. Sarkis and Sundarraj (2006) argues that ANP relies only on the experience and knowledge of decision makers included in the process.

According to Kahraman et al. (2006), ANP needs to simulate human thinking in order to reach to accurate judgment. Verbal judgments are vague and unclear and cannot be described in detail for the most part. For example, 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. Fuzzy AHP (FAHP) and Fuzzy ANP (FANP) were introduced to simulate uncertainty in the evaluation process, as human judgment is mostly uncertain and subjective. FANP was used for overcoming uncertainty in AHP, ANP and for considering interdependencies between factors. In basic calculations in ANP are carried out similar to AHP, however weighted, unweighted and limit matrices are introduced to these calculations. Limited matrix calculation is a continuous process of raising the weighted matrix to large powers until reaching to a duplicated matrix (Adams 2001). Whenever the weighted matrix diagonal is one of zeros, the limited matrix turns into a matrix of zeros. If the matrix has columns of zeros (sinks) resulting from no relations between factors, it affects the limited matrix as well. Therefore, the same columns from the identity matrix replace these sinks.

2.7.2 Fuzzy Set Theory (FST)

Zadeh (1965) developed the Fuzzy Set Theory (FST) to eliminate vagueness and imprecision in human interaction within the real-life system by modeling this uncertainty. Conventionally, there are two kind of sets (crisp or fuzzy) to which any element can belong. In the crisp set, membership function can be 0 or 1 as the element either belongs to the set or not. The fuzzy set provides partial membership ranging from 0 to 1.

2.7.2.1 Fuzzy Linguistic Scales

Etaati (2011) stated that the most used FANP scales are Cheng, Kahraman and Saaty. These are not the only ones used, as researchers who use the fuzzy scale can choose the most appropriate one for their research or define their own scale. Cheng (1999) developed his scale based on an integration between linguistic and quantitative variables, using hierarchy to solve any problem as shown in Table 2.4 (El Chanati, 2014).

Kahraman (2006) introduced an integrated framework between fuzzy – QFD (Quality Function Deployment) and a fuzzy optimization model to determine the technical requirements for designing a product. Saaty (1989) presented his own fuzzy scale, which was composed of nine points and was widely used for AHP and ANP pairwise comparisons by several researchers as shown in Table 2.4.

Table 2-4: Fuzzy linguistic scale (Chanati, 2014)

Scale	Fuzzy Linguistic Scale
Cheng	{(0,0,0.25); (0,0.25,0.5); (0.25,0.5,0.75); (0.5,0.75,1); (0.75,1,1)}
Kahraman	{(1,1,1); (0.5,1,1.5); (1,1.5,2); (2,2.5,3); (2.5,3,3.5)}
Saaty	{(1,1,1); (2,3,4); (4,5,6); (6,7,8); (8,9,10)}

2.7.2.2 Fuzzification

Grima, et al. (2000) defined fuzzification as a transformation process that changes inputs as crisp values into output of grades using membership functions and linguistic terms. Membership functions can take different forms depending on the problems to be fuzzified, the variables (inputs and outputs), and expert opinion. These functions can be linear or non-linear (Abouhamad, 2015). Ross (2010) argues that linear functions are used most in engineering for their accuracy and simplicity. Linear functions forms are triangular and trapezoidal, while non-linear forms can be S-shaped or Bell-Shaped. However, choosing the most suitable membership function is highly complex.

2.7.2.3 Defuzzification

Defuzzification is the opposite of fuzzification as it transforms fuzzy sets back into crisp values. Three methods are used for defuzzification: the Bisector of Area (BOA), Centroid of Area (COA), Mean of Maximum (MOM), Largest of Maximum (LOM), and Smallest of Maximum (SOM). The most widely used method is the centroid of area (COA) as it takes all active rules into account during defuzzification (Abouhamad, 2015).

2.7.2.4 Triangular Fuzzy Number

One of the well-known forms of linear fuzzy number is triangular fuzzy numbers (TFN), represented as $M = (l, m, u)$ - $l \ll m \ll$u and they refer to the lower, moderate and upper values of the membership function respectively. Triangular membership function is absolutely the most suitable function for this form.

2.7.3 The FANP Approach

At first, an evaluation and selection index on four levels is proposed for establishing the relationship among attribute enablers and dimensions. During problem evaluation and selection, experts usually specify their preferences in natural language.

One variable of fuzzy linguistic has a value representing the range between artificial and natural language, which underlines the varied linguistic registers we use. The meaning or value of a linguistic element should appear in the outcome variable with the same linguistic factor. Variables describing a human sentence or word can be divided into various criteria of linguistics (i.e. equally valuable, moderately valuable, valuable, very valuable, and extremely valuable). This study uses a 9-point scale for the relative value of compared pairs as shown in Table 2.5.

Linguistic scales of relative importance are used to compare pairs by the top organ of decision-making. The linguistic scale is positioned in the most relevant cell against the numbers of triangular fuzzy. All matrices used in fuzzy numbers are produced the same way. The local weight of factors and sub-factors can be calculated if they are present in ANP's second and third levels as determined by the Fuzzy Preference Programming (FPP) method.

Table 2-5: Linguistic scales of relative importance (Chanati, 2014)

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equally important(EI)	(1,1,1)	(1,1,1)
Intermediate1(IM_1)	(1,2,3)	(1/3,1/2,1)
Moderately important (MI)	(2,3,4)	(1/4,1/3,1/2)
Intermediate2(IM_2)	(3,4,5)	(1/5,1/4,1/3)
Important(I)	(4,5,6)	(1/6,1/5,1/4)
Intermediate3(IM_3)	(5,6,7)	(1/7,1/6,1/5)
Very important(VI)	(6,7,8)	(1/8,1/7,1/6)
Intermediate4(IM_4)	(7,8,9)	(1/9,1/8,1/7)
Absolutely important(AI)	(9,9,9)	(1/9,1/9,1/9)

2.7.3.1 Fuzzy Preference Programming (FPP)

Studies in various fields used fuzzy theory for its simplicity and improved outputs. Van Laarhoven and Pedrycz (1983) applied the Fuzz theory to obtain a fuzzy logarithmic methodology of least square in obtaining fuzzy weight from the matrix of triangular fuzzy comparison. Chang (1996) used an extensive analysis method to provide crisp values for fuzzy matrices. Xu (2000) invented the fuzzy least squares priority method (LSM). Csutora and Buckley (2001) came up with a lambda-Max method. Milkhailov (2003; 2004) designed the Fuzzy Preference Programming (FPP). The fuzzy logarithmic method of least square was modified by Wang et al (2006) for calculating all local priorities for crisp at once for ANP. It is easier to use MATLAB to calculate Fuzzy Preference Programming (FPP) and obtain the local weight from the fuzzy matrices (Mikhailov, 2003; 2004). The first MATLAB code to solve the FANP was presented by Zhou (2012) and later modified slightly by El Chanati (2014). This study is based on the latter code.

This matrix is based on interdependencies found in the network. It is also known as a partitioned matrix whereby each matrix comprises a set of relationships between attribute-enablers and dimensions in the graphic model. Since each column comprises various eigenvectors that add to a single value (in a stochastic column), the whole columns may form an integer value larger than one. Consequently, the unweighted super matrix should be stochastic as a way of deriving it. The weighted super matrix will not reflect a steady state until the row values converge to the same values of each matrix column. This way, it is possible to achieve the limit super matrix. To obtain a comprehensive weight of individual indexes, we need to multiply the weight of the criterion level indicator, the interdependent sub-index, and the independent sub-criterion.

2.7.4 Preference Ranking Organizing Method for Enrichment Evaluation (PROMETHEE)

Brans and Mareschal (1986) designed a method of ranking organizations by preference. It is one of the most used techniques for ranking and has been widely adopted in water management, as well as in waste management (Hokannen and Salminen, 1997). The selection process considers all factors influencing the choice of an alternative over another and those ranging hierarchically from main factors to sub-factors. The different alternatives which are then managed, these alternatives are comprised of different solutions from which the decision maker chooses. Having no specific method for weighing the criteria, decisions makers or experts assign it. Brans and Mareschal (1986) stated that the sum of the criteria weights should always be one.

Salminen (1997) developed a weighting method using summation and normalization based on a score from 1 to 7, 1 being the least important. Roberts and Goodwin (2002) presented three methods of weighting criteria. The first one, a direct rating method, was developed by Von winterfildt and Edwards (1986) and can be implemented using either Salminen's method (1997) or Goodwin and Wright's (1998). The second method is point allocation method. This method considers that the decision maker has 100 points that should be distributed over the criteria to get the weight. Baron and Barett (1996) believe no accurate way of measuring weight exists and most calculated weight depend mainly on the method; the decision maker is more comfortable ranking the criteria than setting weight.

Many methods (e.g. rank order centroid (ROC), rank sum (RS) and rank reciprocal weight (RR)), transform ranking into weight. Kangas et al. (2001) and Macharis et al. (2004) think PROMETHEE criteria weight could be evaluated using Analytical Hierarchy Process (AHP). Semaan and Zayed (2006) presented the first application for measuring PROMETHEE weight using AHP. Since Brans and Mareschal (1986) state no specific technique for evaluating criteria, the assessment could be quantitative for objective criteria and qualitative for subjective criteria. Fuzzy set theory, as Goumas and Lygerou (1998) show in their model using PROMETHEE, could be used as a ranking method to evaluate the criteria. Being flexible enough to consider different input and evaluation methods for each criterion within PROMETHEE is one of its main advantages and probably the chief reason for its being one of the most powerful MCDM.

One of the advantages of PROMETHEE is that it can support Pseudo. The goal of pseudo is to transform the true criteria into pseudo criteria. According to Roy (1987), this concept is advantageous for having more precise values, providing deterministic solutions, and considering uncertainty. Pseudo is composed of two thresholds-preference and indifference- and a general preference function that chooses one alternative over another using the thresholds. The two thresholds could be expressed together in a mathematical function, the generalized preference function. The latter facilitates the process of considering uncertainty in the criteria values, but building this function is complex and so far most researchers have expressed significant doubts about it. According to Goumas and Lygerou (1998), the generalized preference function could be expressed either in a fuzzy way or in a crisp expression. Brans (1986) presented six types of Crips GPF as sown in Figure 2.5. If functions do not fit the criteria, the decision maker can define his own GPF (Gelderman and Rentz, 2000) as shown in Figure 2.6.

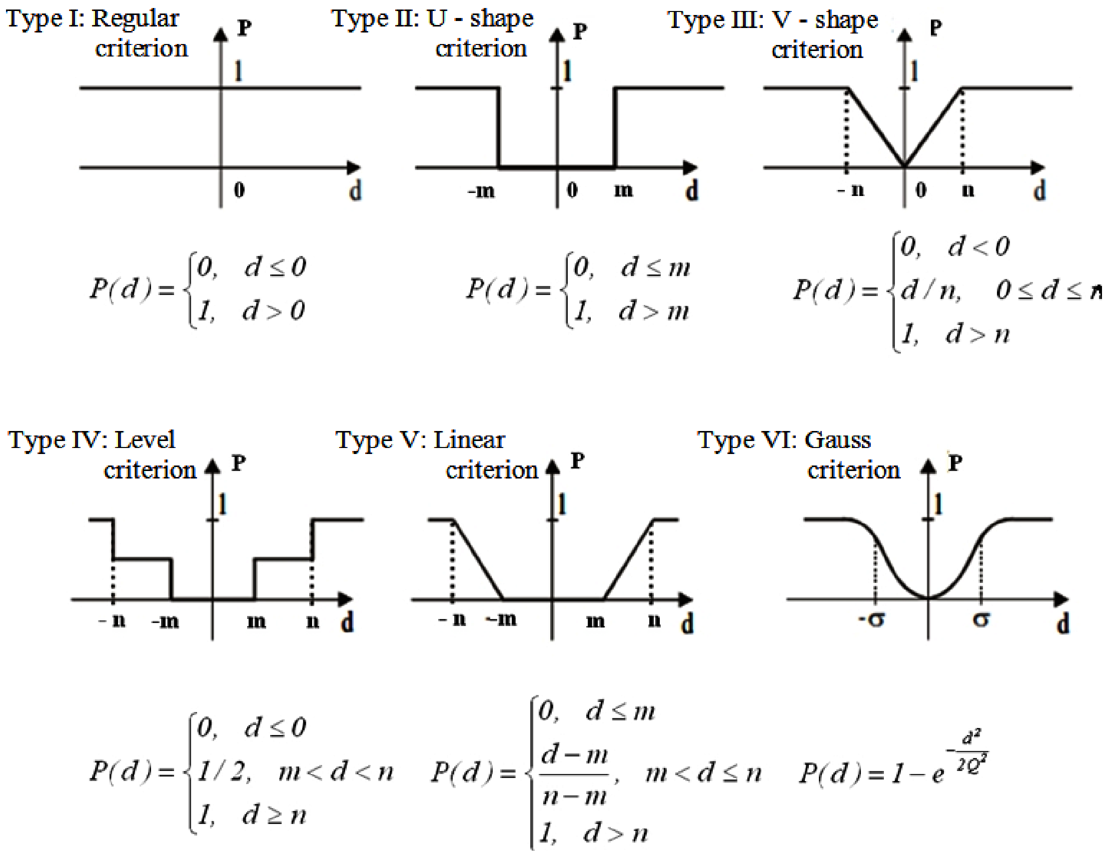


Figure 2-5: Types of GPF (Brans, 1986)

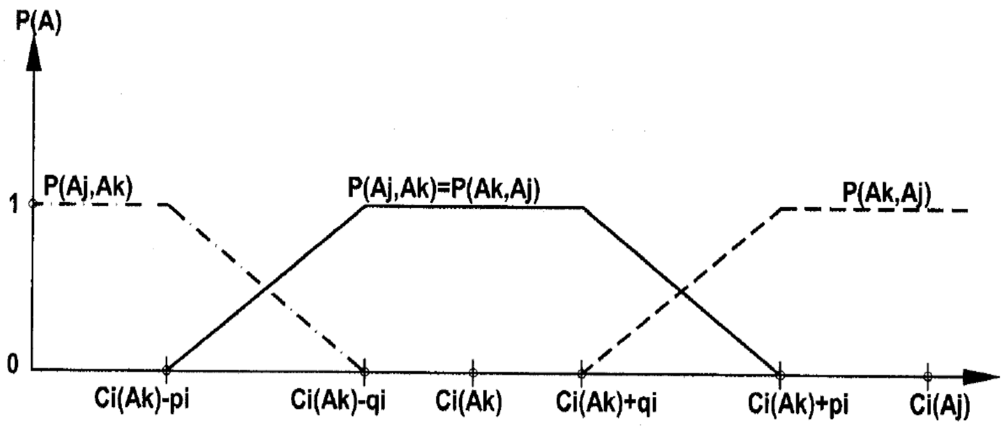


Figure 2-6: Generalized Preference Function (Semaan, 2006)

Therefore, the preference function is defined as follows:

$$\mathrm{P}\left[C_i\left(A_j, A_K\right)\right] = 1 \text{ if } C_i(A_K) - C_i\left(A_j\right) \geq P_i(C_i) = A_K \mathrm{P} A_j \qquad [2.1]$$

$$0 \text{ if } C_i(A_K) - C_i\left(A_j\right) \leq q_i(C_i) = A_K \mathrm{I} A_j \qquad [2.2]$$

Otherwise = $A_K Q A_j$ [2.3]

Where;

P= Strong Preference, I= Indifference Preference, Q= Weak Preference

The aggregation in PROMETHEE is performed as pairwise comparison between the alternatives. As it starts with calculating $(Aj,)$ for all the criteria and then the preference index that is multi criteria, which is the weighted preference value of options $AjtoAk$ considering all criteria is calculated as per equation 2.4

$$\pi(A_j, A_K) = \Sigma_{i=1}^{n} W_i * P_i(A_j, A_K) \quad [2.4]$$

From the multi criteria preference index, the measure of strength (the leaving flow) of any alternative over other alternatives and the measure of weakness (the entering flow) as shown in Figure 2.7 for any alternative over other alternatives can be calculated using equations 2.5, 2.6 and 2.7.

$$\phi^{+}(A_j) = \Sigma_{j=1}^{m} \pi(A_j, A_K) \quad [2.5]$$

$$\phi^{-}(A_j) = \Sigma_{j=1}^{m} \pi(A_k, A_j) \quad [2.6]$$

While the net flow is calculated as:

$$\phi^{net} = \phi^{+}(A_j) - \phi^{-}(A_j) \quad [2.7]$$

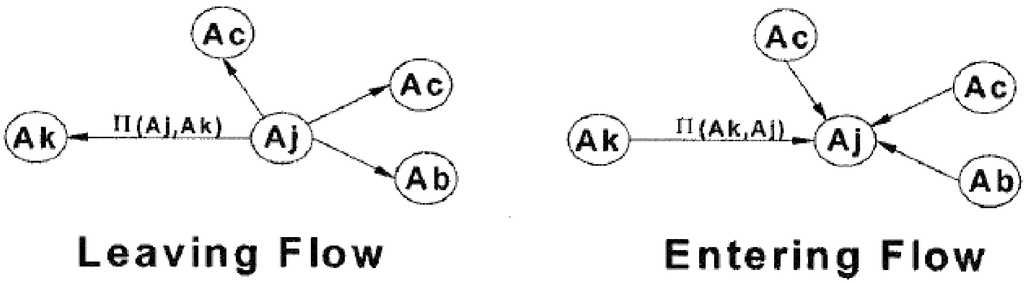


Figure 2-7: Flow diagram (Semaan, 2006)

Brans and Mareschal (1986) presented two ranking methods; PROMETHEE I and PROMETHEE 2. The ranking is done solely in the presence of the leaving flow $\Phi+$ in PROMETHEE I. While, PROMETHEE 2 classifies the values of the alternatives per the net flow Φnet. Therefore, PROMETHEE I allow the same rank to have two alternatives, whereas PROMETHEE II provides a unique ranking for every alternative as shown in Figure 2.8.

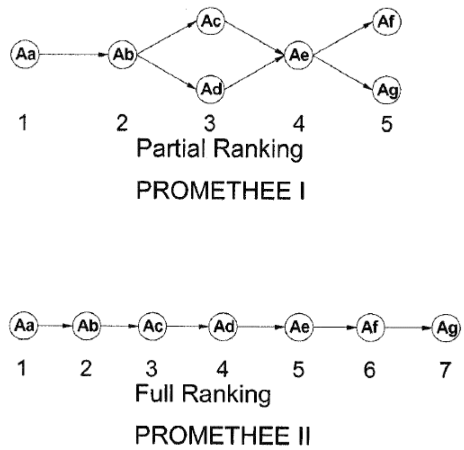
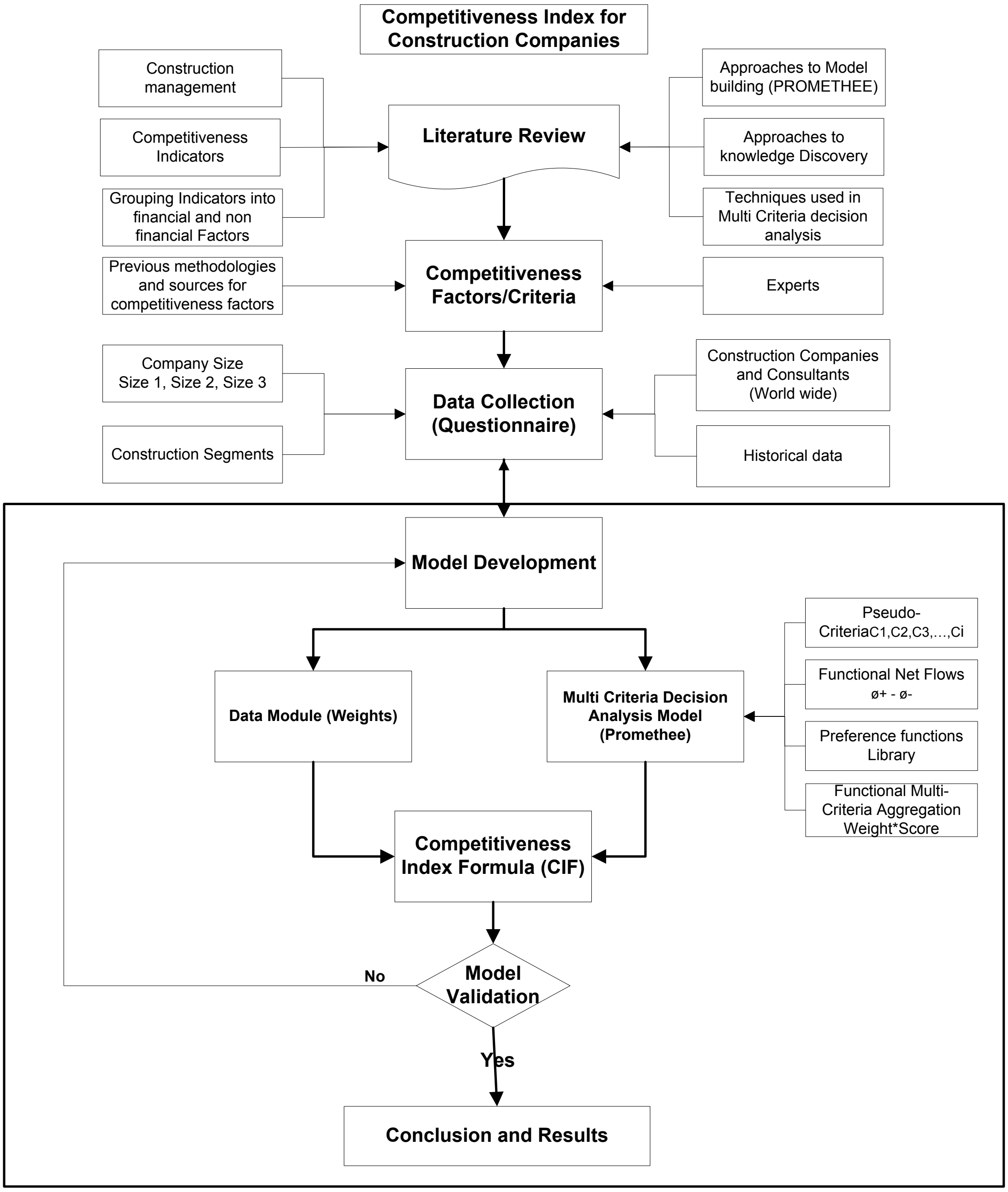


Figure 2-8: Flow diagram (Semaan, 2006)

CHAPTER 3: METHODOLOGY

3.1 Introduction

The proposed competitiveness assessment model should consider limitations of previous works and addresses underlying challenges in construction companies. This section comprises the following sub-sections, including literature review, model development and model implementation. The literature review, previously discussed in chapter 2 offers a description for some of the techniques used in this research and major findings of the previous research studies addressing competitiveness in construction companies. The model development section proposes the development of competiveness assessment model for construction companies and covers factors identification, data collection, FANP-based weights for the identified factors and implementation of PROMETHEE to determine competiveness. Finally, the model implementation chapter covers the implementation of the developed model over the different case studies gathered from construction companies. Figure 3.1 shows the methodology adopted in this research to develop the competitiveness evaluation model.



Contribution:

- Generalize competitiveness index for construction companies
- Eliminate subjectivity and uncertainty when identifying performance evaluation functions
- More gathered data which will benefit in reducing the uncertainty and leading to more realistic results

Objectives:

- Identify and study financial and non financial factors for competitiveness of construction companies
- Determine and develop competitiveness index formula (PROMETHEE)
- Develope a dynamic user's interface for companies competitiveness index based on the industry type and company size

Figure 3-1: Research methodology

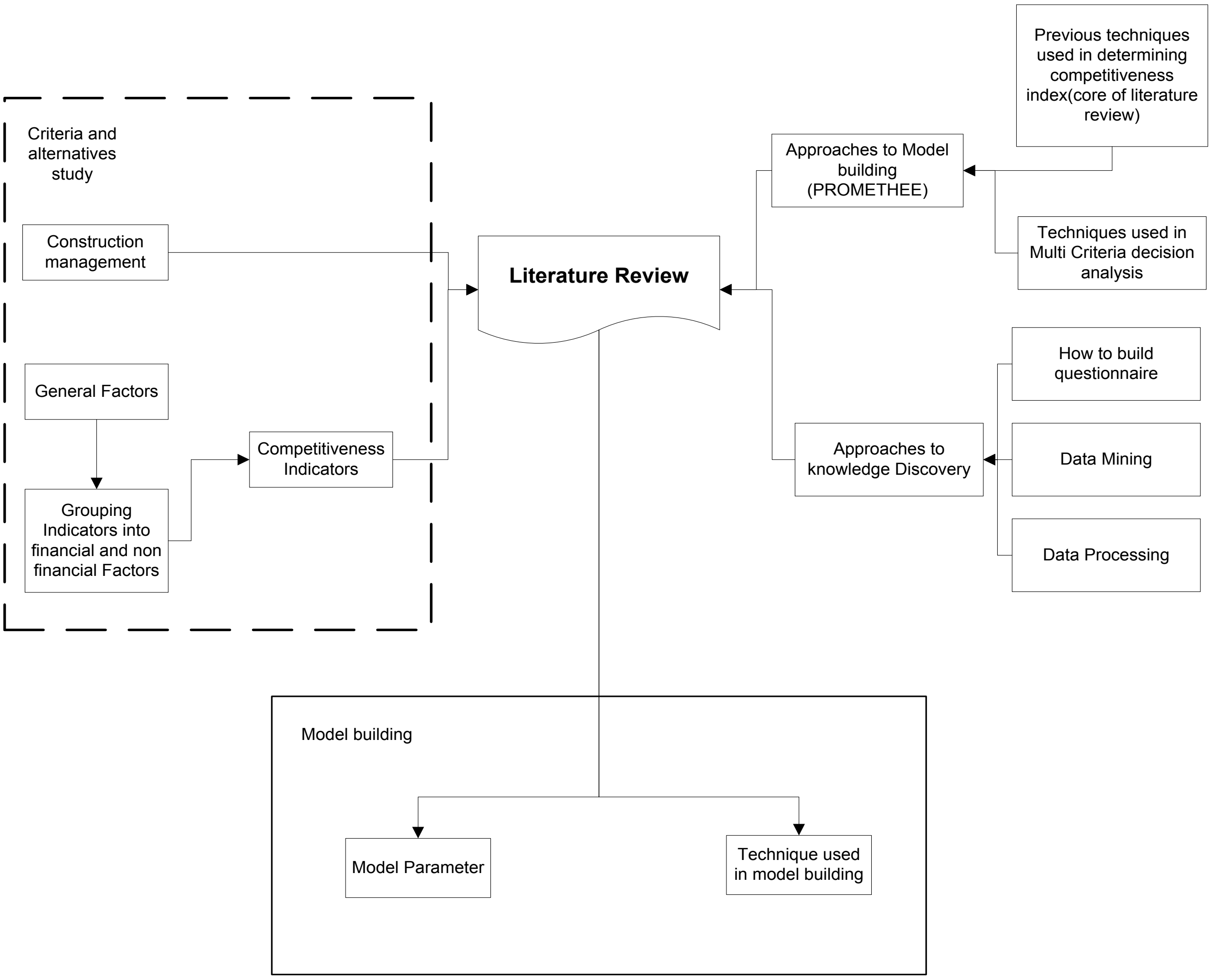


Figure 3-2: Literature Review

3.2 Factors Identification

The literature review, discussed in Chapter 2, is performed in identifying the importance of factors affecting the competitiveness of construction companies and to come up with a solid background concerning competitiveness by studying the previous competitive theories figure 3.2 shows the methodology adopted in this research to develop the literature review. Several factors are important while assessing construction companies' competitive ability of construction companies with respect to the respective challenges. The proposed model is developed based on the factors chosen from the literature review. Expertise opinions are also included in the factors' identification process through several meetings. Figure 3.3 summarize the identified factors that contribute to competitiveness and experts' opinions. The included factors are categorized into three main pillars: external, internal, and financial category of construction companies and related projects.

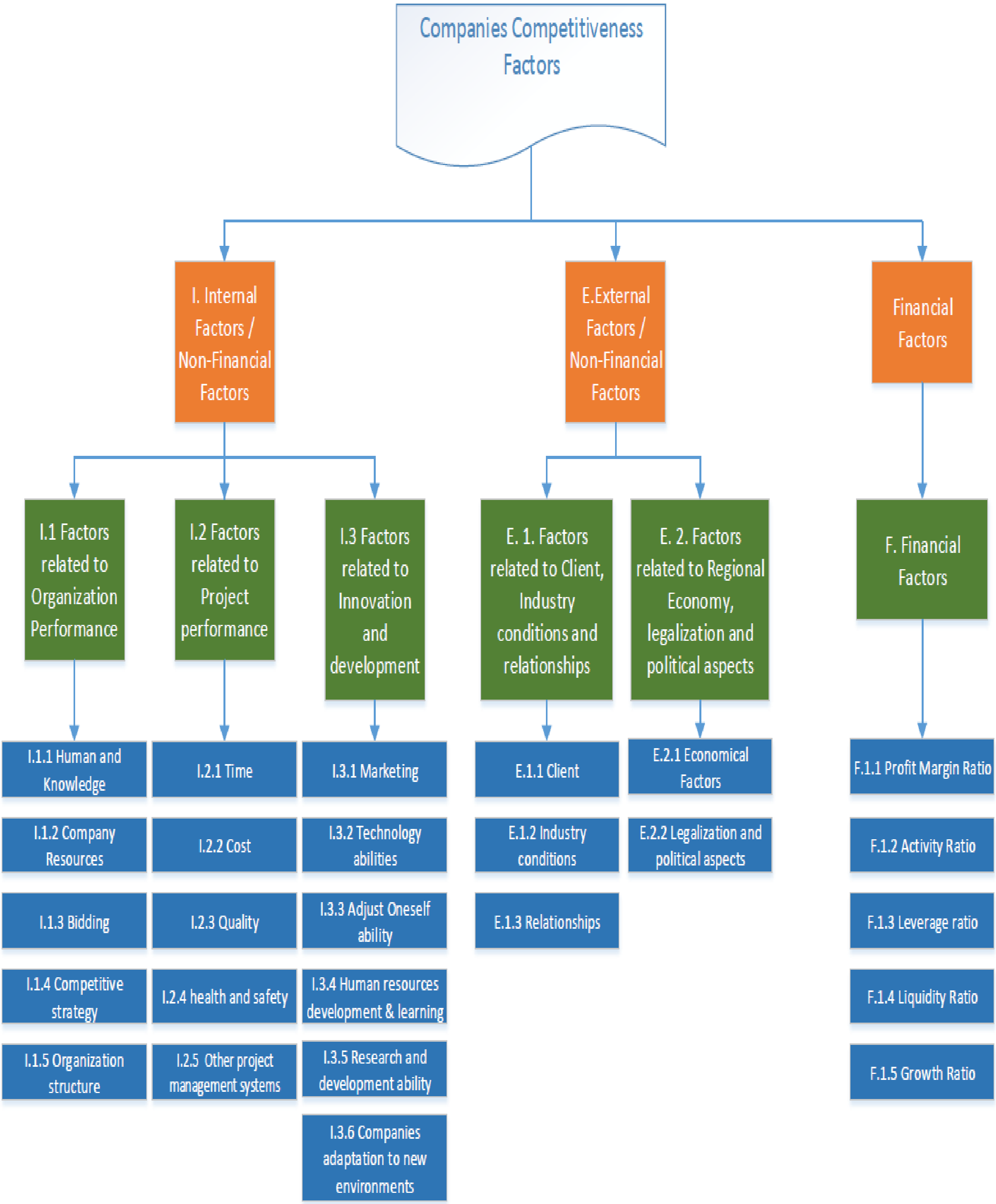


Figure 3-3: Companies Competitiveness Factors

3.2.1 The 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 organization performance where construction organizations should take into consideration in labor skills and experts' as to establish a competitive strategy that is sufficiently feasible. Advancements technology and knowledge of construction firms require additional cooperation, education, and the management of strategy at a company level. The organization performance includes the factors of:

3.2.1.1 Human and knowledge

Most competitiveness consider human resource and 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.

3.2.1.2 Company Resources

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

3.2.1.3 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 availability of resources, experience for bidding, and professionals for bidding.

3.2.1.4 Competitive Strategy

Every firm in the corporate world has a well-defined competitive strategy that outlines its mission, vision, and goals of the company. They are used as tools for enhancing the competitiveness awareness in the course of inventing 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.

3.2.1.5 Organizational Structure

When a company seeks to become relevant in the international scene, the management team are supposed to have a clear consideration of its global standing in the wake of competition. Communication protocols between projects, departments, customers, staff, and stakeholders should be as clear as possible.

The second category concerns project performance. Quality, time and cost 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, cost, quality, and health and safety.

The third category that is important in project management include 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 their labor attractiveness and improve recruitment conditions. 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. In addition, a company should also show exemplary performance in Information Communication and Technology to remain up to date with technological changes the factors of innovation and development include:

3.2.1.6 Marketing

This is one of the critical factor to consider while addressing the competitive strategy of construction firms. Imperatively, markets are constantly developing thanks to consistent technology. In such situations, there are a lot of orders from clients and the experience that a construction firm will reflect determines its overall performance.

3.2.1.7 Technical 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 IT is that it virtually connects customers, project managers, and staff in a single network.

3.2.1.8 Flexibility

Making necessary adjustments and being flexible are also important for achievable competitiveness levels. With respect to the increase in global competition, construction firms are supposed to adopt to changes in the external environment and ensure that their business models are compatible with the business environment in the global context.

3.2.1.9 Learning and Development

Executives should lead their companies to establish a system of research and development (R&D) to seek new knowledge. This is a core competency asset that offers the right tools of dealing with challenges.

3.2.1.10 Adaption to New Environments

The current environment marred with diversities and complexities demands that organizations should have intelligent teams. These include ones that place special emphasis on reaching out to stakeholders and easily adopt to flatter organization structures.

3.2.2 The 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 client, 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.

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 significant impact on the highly competitive environment. The relationship with suppliers, sub-contractors, consultants, designers, the public sector, and government departments are supposed to be addressed within the shortest time possible. The following are the factors included in the first category of the external pillar:

3.2.2.1 Client

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.

3.2.2.2 Industry Conditions

The sub factors under the industry conditions that should be analyzed include things such as the public sector, market laws and regulations, government departments and others.

3.2.2.3 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.

The second category includes factors of:

3.2.2.4 Economic factors

Economic conditions are essential; the attractiveness of contracting with foreign currency and Recession in the domestic construction market are vital for competitiveness

3.2.2.5 Legalization & political aspects

Company competitiveness is sensitive when it is to be faced by these aspects such as; Corruption and lack of transparency, political instability, inconsistencies in government policies and laws, health and safety issues, procurement act and legislation, lack of government guarantees and demand for construction.

3.2.3 The Financial Pillar

The financial pillar is a group of factors that shows how the company is performing financially. Also, 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 for factors that affect a company’s competitiveness and are described in details below.

3.2.3.1 The Ratio of Profit Margin

Also 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.

3.2.3.2 Activity Ratio

Also known as the management ratio or operating ratio, it measures a company's efficiency of using its assets to realize value.

3.2.3.3 Leverage Ratio

Also known as the debt to equity ratio. It offers a glimpse 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.

3.2.3.4 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.

3.2.3.5 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.

3.3 Construction Companies Competiveness Evaluation Model Development

A questionnaire survey and experts interview were the data collection instruments used in the study. 17 experts from several countries working in the construction industry with different level of expertise were interviewed. These experts were sought to fill in the questionnaires shown in the appendix section from which the relative importance was determined for the different affecting factors. Additionally, 5 experts from two regions were interviewed to provide data for the case studies and the validation of them. FANP was applied in the relative calculation of the pillars and factors weights. Two criteria types exists, including that of soft and hard data in this research. The former comprised factors such as the “ability to adjust oneself” or “client relationship” were based on the subjective assessment of experts. On the other hand, hard data refers to a company’s statistics, such as the productivity of employees, financial factors, and others. The developed model was based on the factors that were chosen from the literature review section and the argument of experts.

FANP serves to calculate the weights of importance of the factors that affect the competitiveness ability for construction companies. To utilize FANP, the following steps were implemented. The first step was to identify the factors that affect the competitiveness ability for construction companies. Second, was to categorize the identified factors under the relevant category based on the literature review and experts’ opinion, as previously illustrated in Chapter 2. Third, was to collect the data based on questionnaire. Fourth, was applying fuzzification scale to overcome the uncertainties from the collected data.

The proposed model utilized the widely used MCDM technique known as the PROMETHEE. The following section describes how PROMETHEE was used in developing the proposed model.

3.3.1 Local Functional and Global Thresholds

This technique ranks criteria; however, as the main disadvantage, this ranking is not on an ordinal scale, or a fixed one based on fixed numbers but it is just a rank. Therefore, to overcome this disadvantage, upper and lower datum; representing the threshold of factors were developed. The datum can be best defined as per Equations 3.1 and 3.2:

$$v_i[c_i(C_0)] = 0 \qquad [3.1]$$

$$v_i[c_i(C_m)] = 10 \qquad [3.2]$$

Where;

vi[ci]= the competitiveness index of the component

C_0 = Lower Datum Threshold (Weak factor)

C_m = Upper Datum Threshold (Strong factor)

Therefore, the ranking for companies can be within the newly defined cases.

3.3.2 Evaluation of Criteria in PROMETHEE

One of the advantages of PROMETHEE is that Pseudo concept can be applied within it. The main concept of pseudo is transforming the true criteria into pseudo criteria. According to Roy (1987), the advantages of pseudo concept can be summarized into; considering more precise values, provide deterministic solutions and considering uncertainty. Pseudo concept is composed of two thresholds; the preference threshold and the indifference threshold and it is composed of general preference function. It prefers one alternative to the other using those thresholds.

The two thresholds could be expressed together in a mathematical function, named the generalized preference function. This function is used to facilitate the process of considering uncertainty within the criteria values, but building this function is a complex process and so far, most of the researchers have a high uncertainty about it. According to Goumas and Lygerou (1998), the generalized preference function could be expressed either in a fuzzy way or in a crisp expression. Brans (1986), presented six types of Crips Generalized Preference Function (GPF). To represent the thresholds compared to both the lower and upper defined limits, the GPF is used. The GPF trade-off points are the tolerance and critical thresholds as presented in Figure 3.4.

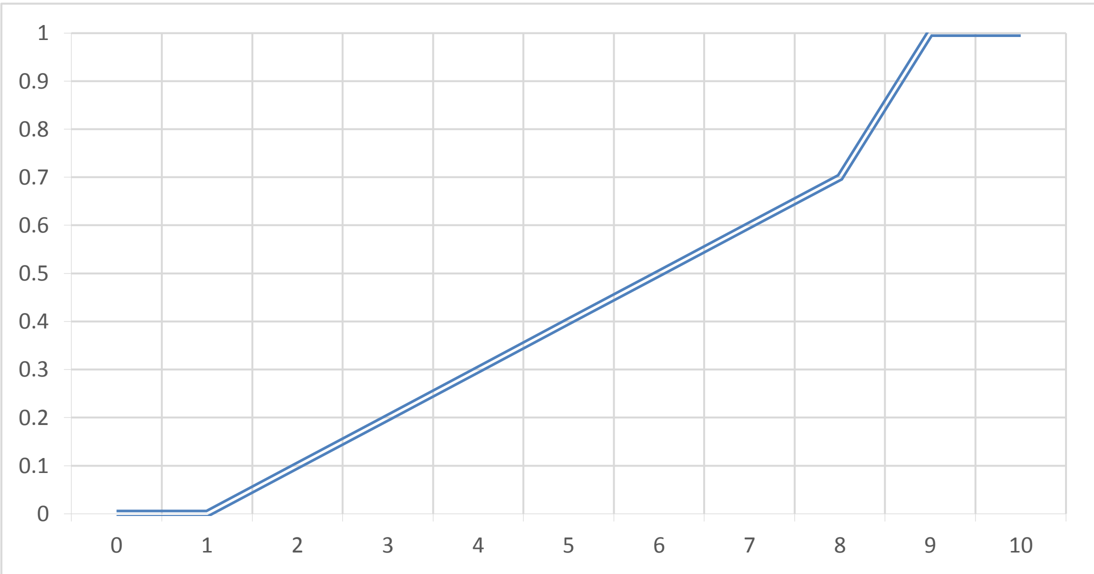


Figure 3-4: Competitiveness Index Evaluation Generalized Preference Function

PROMETHEE considers the uncertainties and imprecision within the model. It is mainly based on two boundaries defined as indifference threshold and preference threshold for each factor. Thus, by defining the lower datum = 0 that represents weak factor and the upper datum = 1 that represents a strong factor, the two thresholds are transformed into two physical limits as follows:

1) Critical Threshold (CT) is the limit value of each factor Ci beyond which it is considered Weak or critical.

2) Tolerance Threshold (TT) is limiting value of each factor Ci below which it is considered Strong or tolerable.

When the preference = 0, the component performance index equals to or is lower than the critical threshold. While the preference = 1, the component performance index is greater than the tolerance threshold. If the performance is higher than the critical threshold and lower than the tolerance threshold, the preference should be calculated using Equation 3.3

$$\boldsymbol{Pc_n} = \frac{(\mathrm{vn[cn]} - \mathbf{CT})}{(\mathbf{TT} - \mathbf{CT})} \quad [3.3]$$

Where;

Pc_n= The preference of the factor, vn[cn]= the competitiveness index of the component

CT= Critical threshold

TT= Tolerance threshold.

3.3.3 Multi-Criteria Aggregation

Multi-criteria aggregation can be done based on Equations 3.1 and 3.2 while the ranking for any specific factor is within the newly defined datum as per Equations 3.4 to 3.12.

$$P_i(C_0, C_0) = v_i[c_i(C_0)] - v_i[c_i(C_0)] = 0 \quad [3.4]$$

$$P_i(C_0, C_n) = v_i[c_i(C_0)] - v_i[c_i(C_n)] = -\mathrm{ve} < 0 \quad [3.5]$$

$$P_i(C_0, C_m) = v_i[c_i(C_0)] - v_i[c_i(C_m)] = -10 < 0 \quad [3.6]$$

$$P_i(C_n, C_0) = v_i[c_i(C_n)] - v_i[c_i(C_0)] = v_i[c_i(P_n)] \quad [3.7]$$

$$P_i(C_n, C_n) = v_i[c_i(C_n)] - v_i[c_i(C_n)] = 0 \quad [3.8]$$

$$P_i(C_n, C_m) = v_i[c_i(C_n)] - v_i[c_i(C_m)] = -ve < 0 \quad [3.9]$$

$P_i(C_m, C_0) = v_i[c_i(C_m)] - v_i[c_i(C_0)] = 10 \quad P_i(C_m, C_0) = 1$ [3.10]

$P_i(C_m, C_n) = v_i[c_i(C_m)] - v_i[c_i(C_n)] = +ve$ [3.11]

$P_i(C_m, C_m) = v_i[c_i(C_m)] - v_i[c_i(C_0)] = 0$ [3.12]

Where;

i=1,

C_n= $th\ e$ factor $tobe$ evaluated

C_m&C_0 = the upper and lower limits.

3.3.4 Preference Index

The Multiple Attribute Preference Index of any two components is defined as the weighted average of the preference functions of any component (C_1) to (C_2) as shown in equation [3.13]

$\pi\ [C_1, C_2] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_1, C_2)$ [3.13]

Where; 0≤ $[C_1, C_2]$≤1 and i=1 to (n) is the total number of factors within each factors category. Therefore, for each component compared to the defined limits Cm, $C0$, the following preference functional indices are generated as shown in Equations 3.14 to 3.22.

$\pi\ [C_0, C_0] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_0, C_0)$ [3.14]

$\pi\ [C_0, C_n] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_0, C_n)$ [3.15]

$\pi\ [C_0, C_m] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_0, C_m)$ [3.16]

$\pi\ [C_n, C_0] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_n, C_0)$ [3.17]

$\pi\ [C_n, C_n] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_n, C_n)$ [3.18]

$\pi\ [C_n, C_m] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_n, C_m)$ [3.19]

$$\pi\,[C_m, C_0] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_m, C_0) = 1 \quad [3.20]$$

$$\pi\,[C_m, C_n] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_m, C_n) \quad [3.21]$$

$$\pi\,[C_m, C_m] = \Sigma_{i=1}^{n} W_{ci} * P_i(C_m, C_m) \quad [3.22]$$

Where:

Wci= $the\ weight\ of\ the\ defined\ indicators\ within\ specific\ category$

i = 1, n = $the\ total\ number\ of\ the\ indicators\ with\ in\ one\ indicator\ category$

3.3.5 Factors ranking

The entering flow, leaving flow and net flow are the main evaluation parameters for the ranking in PROMETHEE. The measure of strength of Cn is calculated as per Equations 3.23 to 3.33.

$$\phi^{+}(C_n) = \pi\,[C_n, C_0] + \pi\,[C_n, C_n] + \pi\,[C_n, C_m] \quad [3.23]$$

$$\phi^{+}(C_n) = \pi\,[C_n, C_0] \quad [3.24]$$

$$\phi^{+}(C_n) = \Sigma_{i=1}^{n} W_{ci} * P_i(C_n, C_0) \quad [3.25]$$

The measure of weakness of Cn is calculated as follows:

$$\phi^{-}(C_n) = \pi\,[C_0, C_n] + \pi\,[C_n, C_n] + \pi\,[C_m, C_n] \quad [3.26]$$

$$\phi^{-}(C_n) = \pi\,[C_m, C_n] \quad [3.27]$$

$$\phi^{-}(C_n) = \Sigma_{i=1}^{n} W_{ci} * P_i(C_m, C_n) \quad [3.28]$$

The net flow is calculated as follows:

$$\phi^{net}(C_n) = \phi^{+}(C_n) - \phi^{-}(C_n) \quad [3.29]$$

$$\phi^{net}(C_n) = \Sigma_{i=1}^{n} W_{ci} * P_i(C_n, C_0) - \Sigma_{i=1}^{n} W_{ci} * P_i(C_m, C_n) \quad [3.30]$$

The net flows for $C0$, Cm are:

$$\phi^{net}(C_0) = -1 \qquad [3.31]$$

$$\phi^{net}(C_m) = 1 \qquad [3.32]$$

Finally, the output of the ranking of any factor net flow should be a fixed value between the lower and upper limits [-1, 1].

$$\phi^{net}(C_0) < \phi^{net}(C_n) < \phi^{net}(C_m) \qquad [3.33]$$

3.3.6 Calculating Competitiveness Index

The net flows are used for computing the functional competitiveness index as it can be transformed from a scale [-1, 1] to a functional index scale within the range [0, 10], using a simple conversion equation (Equation 3.34) in a form of straight line as shown in Figure 3.5

$$\boldsymbol{(CI) = [-5 * \phi^{net}(C_n)] + 5} \qquad \textbf{[3.34]}$$

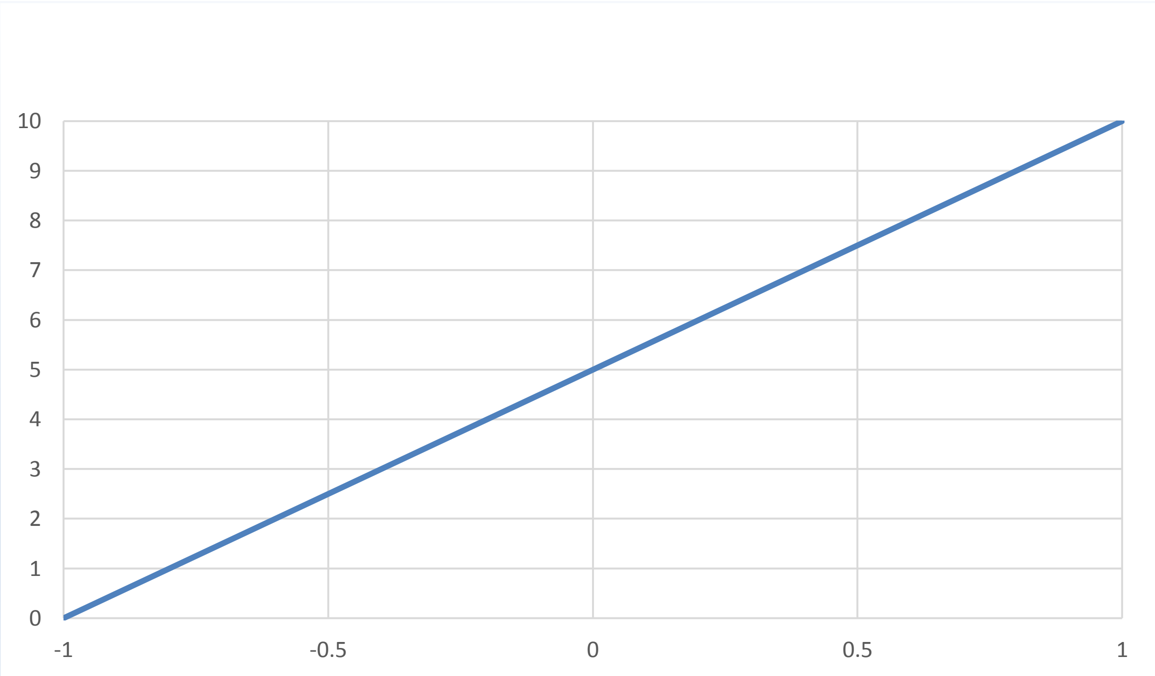


Figure 3-5: Conversion straight line for competitiveness index

3.4 Summary

The chapter mainly offered a brief explanation of the major phases of the methodology. The section commenced with a review of literature. The next parts that followed identified factors affecting the competitiveness of the construction companies. There was implementation of a questionnaire survey to gather main information sets, factors` of relative importance, and their affiliated thresholds. FANP together with the proposed competitiveness assessment model utilize the widely used MCDM technique known as the PROMETHEE.

CHAPTER 4: DATA COLLECTION

4.1 Introduction

For this research the data was collected from many sources that helped develop and operate the proposed competitiveness index model. The first source was the literature review, which provided data on the factors needed to assess competitiveness in construction companies. The second source was the expert opinions and interviews, in which the gathered factors from the literature review were discussed during interviews with experts from the construction industry and from this source. The third source was a questionnaire developed for competitiveness assessment and used to gather the weights of the defined factors and the threshold values from the experts in construction industry.

The experts assessed the importance of the factors and assigned the maximum and minimum thresholds for each factor. The factors' importance provided by the experts were used to perform FANP calculations, thus obtaining the weights of the factors. The questionnaires were reached by professionals in different but related fields of expertise in the construction industry and from different geographical areas. The number of questionnaires gathered were 20, with a response rate of 40%. The last type of collected data was the case studies database. The information found in these case studies were used to assess the validity of the proposed competitiveness index model. Literature review was the first source for the data in this research. This source performed in identifying the effectiveness of factors that impact the construction companies' competitiveness. They were also used in establishing a solid background for their competitiveness.

4.2 Expert Opinions

Through five (5) interviews with senior directors working in major programmes in the construction industry and experts involved in the construction industry in general, the factors were defined and given a quantitative range. The targeted experts were from two (2) locations, Middle East and North America. The interviews took place either online or in-person.

4.3 Questionnaires

The developed questionnaire is as shown in Appendix (A) and it consisted of four parts as follows:

4.3.1 General Information Part

In this part, 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 companies average work load and their company size.

4.3.2 Determining Relative Importance of Factors

The experts were asked in the second part of the questionnaire to fill some tables regarding the weight of importance of the factors. In which experts were guided to provide their opinion for the importance of the factors with the importance from Very Weak to Very Strong for each competitiveness factor. Very low represented the least effect and/or importance while very high represented the most effect and/or importance. These tables were used to conduct a 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.

4.3.3 Pseudo Criteria Thresholds Definition

This section explained the analysis of the information required to set the critical and tolerance thresholds of each of the factors. The scale used for each factor was the same as the quantitative range. The critical threshold was the value for which, according to the nature of the factor, the factor was considered critical if above or below. The tolerance threshold was the value for which, according to the nature of the factor, the factor was considered tolerable or safe if above or below. The gathered responses from this part were considered sufficient to define the thresholds.

4.3.4 Data Analysis

Data was analyzed to reach to a better understanding of the gathered responses and make a better judgment over its accuracy. Thus, the average of the gathered responses was obtained after calculating the relative weights of the factors for each individual response. Then, the percent difference of each response from the average was calculated and the responses with high difference percentage were excluded. Three responses were excluded.

In order to have further analysis, 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 4.1 illustrates 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 a percentage of 50%. Participants with experience between 11 and 15 years of experience represented a percentage of 10% and between 6 and 10 years represented 35% and finally, participants with experience between 1 and 5 years of experience represented a percentage of 5%.

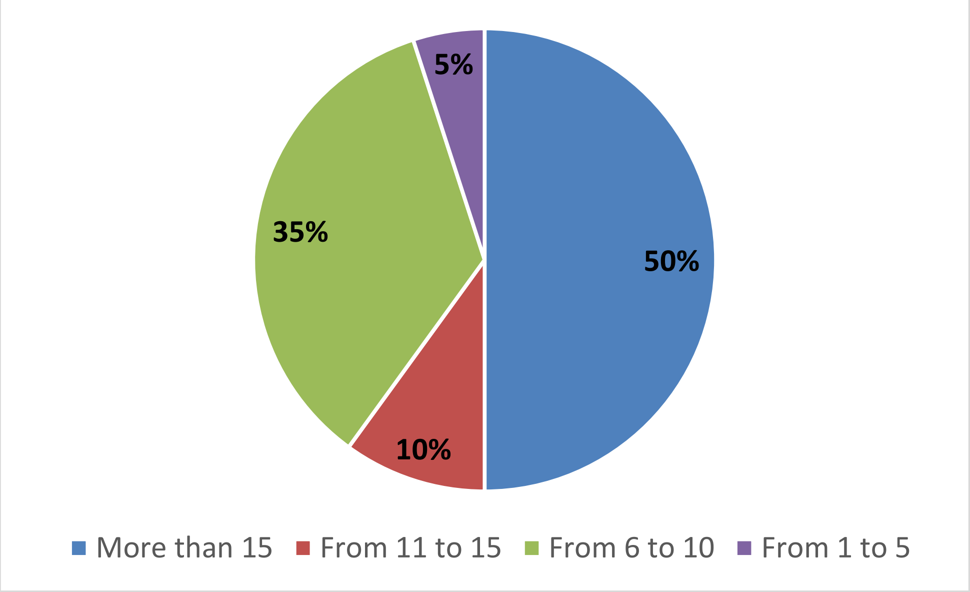


Figure 4-1: Percentage of Respondent by Years of Experience

Figure 4.2 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.

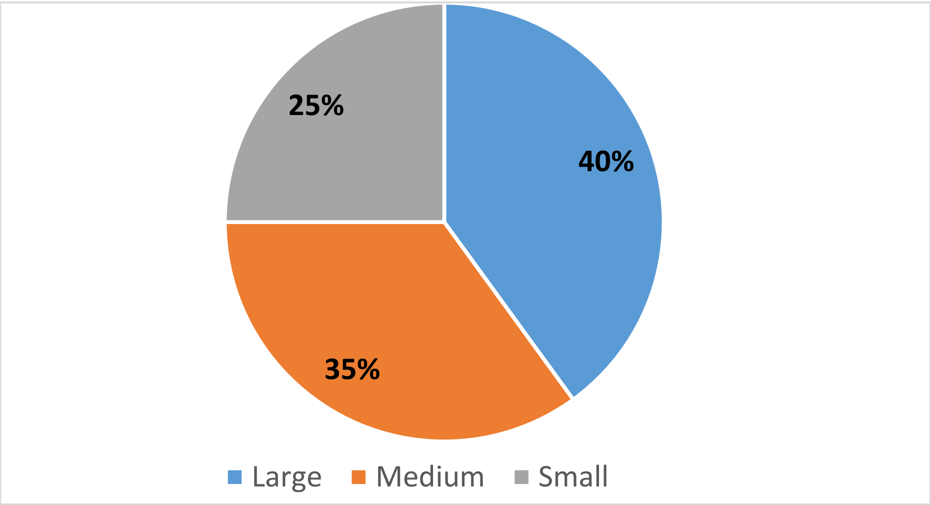


Figure 4-2: Percentage of Respondent by Size of Business

Figure 4.3 shows that the location of professionals was categorized into 7 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.

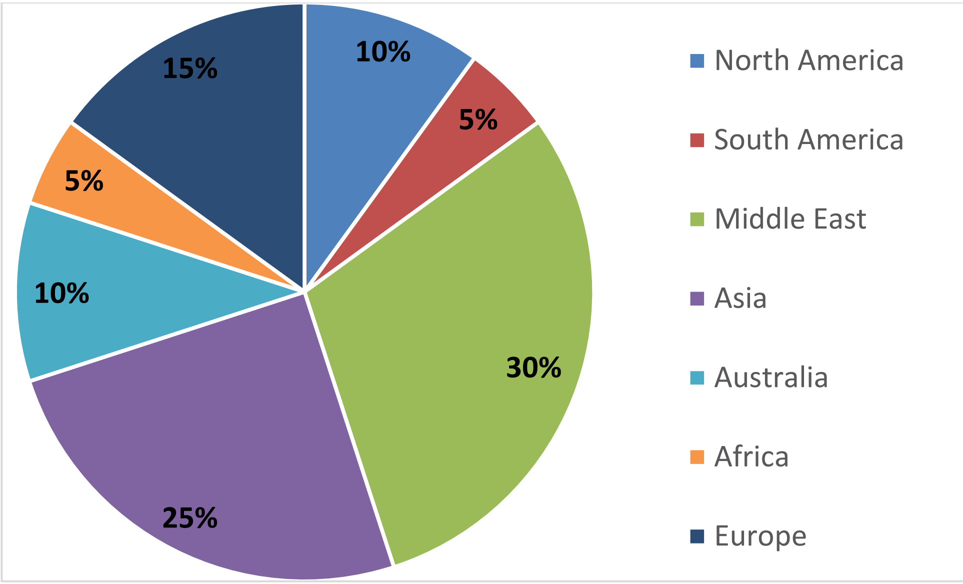


Figure 4-3: Percentage of Respondent by Region

Figure 4.4 shows 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 a percent of 48%, 28% and 24% of the participants in each construction type, respectively.

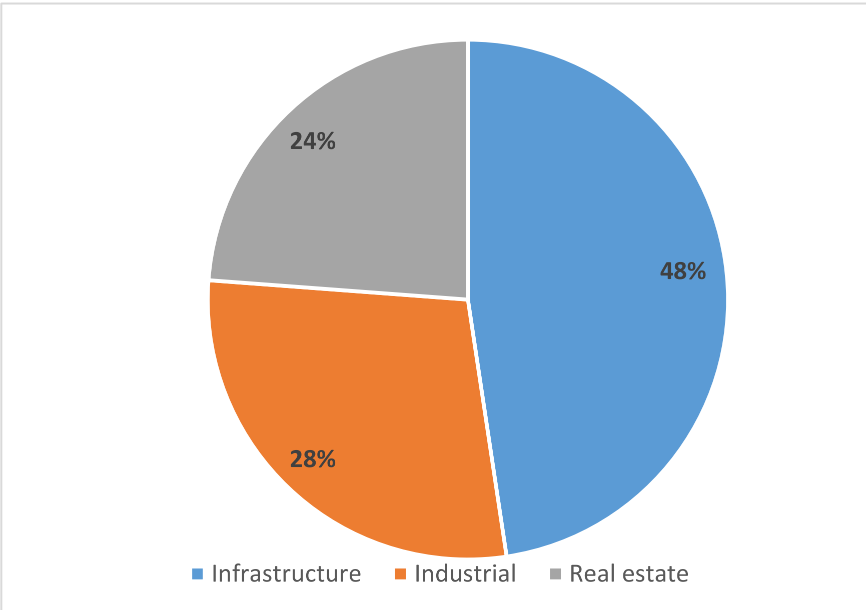


Figure 4-4: Percentage of Respondent by Construction Type

The average degree of importance of each factor for the competiveness was calculated and presented in Figure 4.5. It was found that the factor E.2.2 – legalization and political factor was the most important factor that affect the competitiveness of the construction companies. Meanwhile, the factor I.3.5 – Research and development ability had the least importance.

The average of the thresholds values were also calculated and the outliers have been taken out as well. The average was considered for further research calculations with limited assumptions, to facilitate calculations. As presented in Table 4.1 Pseudo thresholds data were gathered and considered sufficient for the analysis, as participants had defined the thresholds.

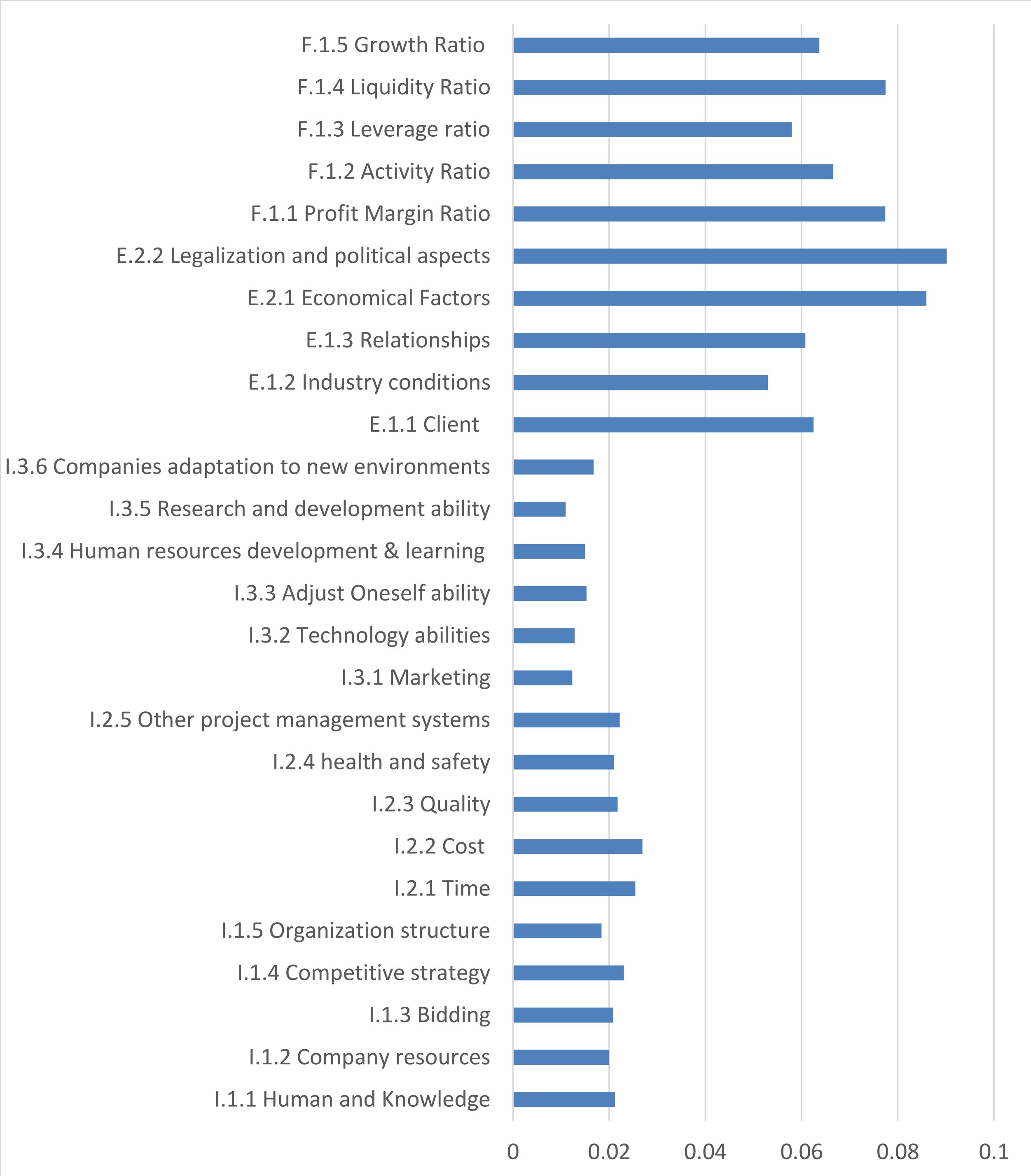


Figure 4-5: Degree of importance of each factor of the competiveness

Table 4-1: Maximum and Minimum thresholds table from the questionnaire

Factor	Threshold	
	Min	Max
I.1.1 Human and Knowledge	75000	175000
I.1.2 Company resources	1	5
I.1.3 Bidding	34	66
I.1.4 Competitive strategy	1	5
I.1.5 Organization structure	3	5
I.2.1 Time	0.775	1.1
I.2.2 Cost	0.838	1.038
I.2.3 Quality	0	5
I.2.4 health and safety	0.75	10.75
I.2.5 Other project management systems	3	5
I.3.1 Marketing	5.8	23.6
I.3.2 Technology abilities	4.75	12.5
I.3.3 Adjust Oneself ability	14	41
I.3.4 Human resources development & learning	2100	5200
I.3.5 Research and development ability	2.4	11
I.3.6 Companies adaptation to new environments	3	5
E.1.1 Client	3	5
E.1.2 Industry conditions	3	5
E.1.3 Relationships	3	5
E.2.1 Economical Factors	32*1018	83*1018
E.2.2 Legalization and political aspects	0.36	0.86
F.1.1 Profit Margin Ratio	9.2	20.6
F.1.2 Activity Ratio	11.28	39.36
F.1.3 Leverage ratio	4.56	34.82
F.1.4 Liquidity Ratio	12.26	32.33
F.1.5 Growth Ratio	15.65	30.78

4.4 Summary

This chapter explained the data collection process,. The data collected from the review of literature, i.e. the first source is about the methodology of different techniques, assessment factors and the widely-used competitiveness theories. Then, several interviews with experts in the construction management field from different locations have been conducted to approve the chosen factors and identify their qualitative and quantitative descriptions. Afterwards, the questionnaire was developed to gather the factors' weights by means of pair wise comparisons. Around 20 questionnaires, with a response rate of 40% were collected.

The responses were analysed to indicate the occupation of the participants in the questionnaire. Their experience years were also presented, with the highest contribution from participants with more than 15 years of experience, followed by 6 to 10 years of experience. The location of these experts was also presented, in which 30% of the experts were from the Middle East and the rest were from Canada. FANP was applied, resulting in categorical weights and factors relative weights. The average of the responses was calculated to have the most reliable weights and exclude the unrealistic responses when determined.

CHAPTER 5: MODEL DEVELOPMENT

5.1 Introduction

This chapter details the process of generating the evaluation model for determining competitiveness. The model is developed using FANP to determine the factors relative weights. Factors' relative weights were considered the main input to PROMETHEE beside the threshold values, reaching to the construction company competitiveness index. PROMETHEE is used herein to calculate the competitiveness indices. To overcome the complexity of the calculations in deriving the global and relative weights using FANP and the large number of factors that would yield in a cumbersome problem, an integrated MATLAB-Excel® interface was developed to do all the FANP and PROMETHEE calculations. The competitiveness index were the main output of this interface. The methodology applied for in developing the model is illustrated as shown in Figure 5.1.

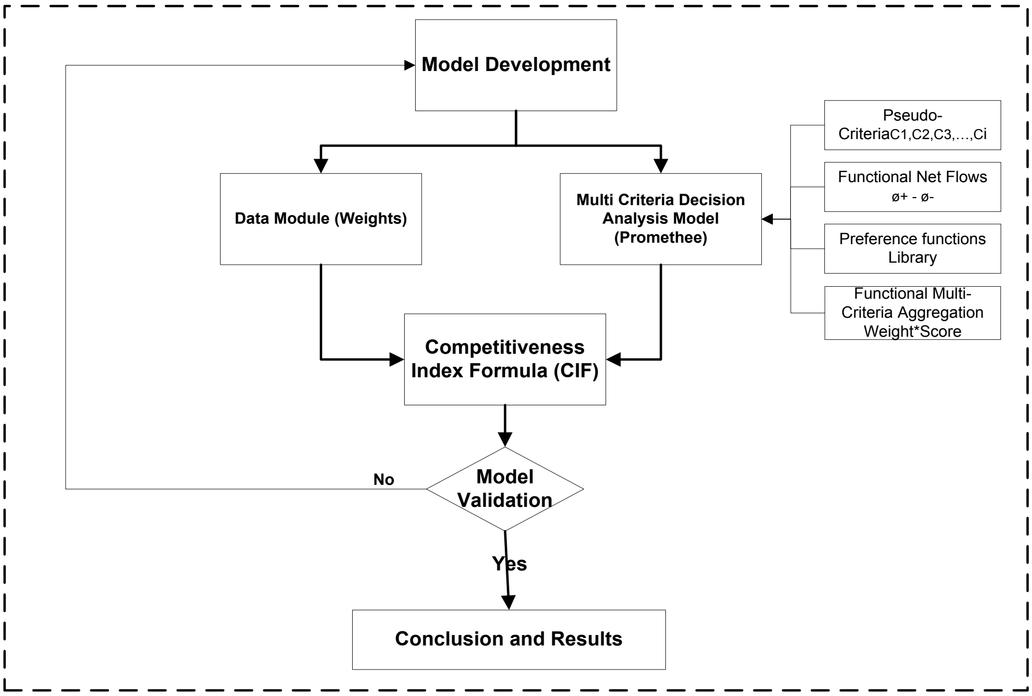


Figure 5-1: Model Development Methodology

5.2 Competitiveness Factors Definition

The model was developed based on weights and importance of the factors collected from the literature review. Expertise opinions were also included in the factors' identification process through several meetings. The included factors were categorized into three main pillars: external pillar, internal pillar, and financial pillar of the organization and affiliated projects. The first step of the competitiveness assessment model was defining the competitiveness factors that would be used. This research was based on 26 factors. This has been discussed in details in Chapter 3 and as shown in Table 5.1.

Table 5-1: Competitiveness factors

Factors		
I. Internal Factors / Non-Financial	I.1. Organization Performance	I.1.1 Human and Knowledge
		I.1.2 Company resources
		I.1.3 Bidding
		I.1.4 Competitive strategy
		I.1.5 Organization structure
	I.2. Project Performance	I.2.1 Time
		I.2.2 Cost
		I.2.3 Quality
		I.2.4 health and safety
		I.2.5 Other project management systems
	I.3. Innovation and development	I.3.1 Marketing
		I.3.2 Technology abilities
		I.3.3 Adjust Oneself ability
		I.3.4 Human resources development & learning
		I.3.5 Research and development ability
		I.3.6 Companies adaptation to new environments
E. External Factors / Non-Financial	E. 1. Client, Industry conditions and relationships	E.1.1 Client
		E.1.2 Industry conditions
		E.1.3 Relationships
	E. 2. Regional Economy, legalization and political aspects	E.2.1 Economical Factors
		E.2.2 Legalization and political aspects
F. Financial Factors	F.1 Financial factors	F.1.1 Profit Margin Ratio
		F.1.2 Activity Ratio
		F.1.3 Leverage ratio
		F.1.4 Liquidity Ratio
		F.1.5 Growth Ratio

5.3 Fuzzy Analytical Network Process (FANP)

The second step in the model development was calculating the relative weights of the defined factors. Fuzzy Analytical Network Process (FANP) was utilized to calculate the weights of importance of the factors that affect the competitiveness ability for construction companies. The first step in deploying FANP was to identify the factors that affect the competitiveness ability for construction companies. Second, the sub factors were categorized under the factors category based on the literature review and experts' opinion, as previously illustrated in Chapter 2. Third, was to collect the data based on questionnaire. Fourth, was to apply fuzzification scale to overcome the uncertainties inherited from experts and human judgment for the collected data. FANP was composed of a series of calculations which will be illustrated through the following part along the ANP as well.

5.3.1 Pairwise Comparison

Experts were asked in the questionnaires about the relative importance between the factors identified and this was done on three levels as mentioned in Chapter 4. The concept of pair-wise comparison is realized through a scale of nine-point (from 1 to 9) as shown in Table 5.2. The comparison analysis assumes the following form: The importance of factor 1 to factor 2 relative to the needs of a user. The pairwise comparison was built using the output of the questionnaires based on "Saaty" scale (Saaty, 1996).

Table 5-2: Scale of Relative Importance (Saaty, 1994)

Intensity of importance	Definition
1	Equal importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or Demonstrated importance
8	Very, very strong
9	Extreme importance

5.3.2 Unweighted Super Matrix

The calculations were done using MS-Excel to calculate the unweighted matrix from the pairwise comparison as presented in Table 5.4. As an example, the number (0.28) represented the relative weight of importance of the "Internal factors category" had among other functions. Accordingly, the number (0.212) for the I.1.1 Human and Knowledge represented relative weight of importance of the Human and Knowledge compared to the other internal factors as shown in Table 5.3.

Table 5-3: Factors weights Using ANP

ANP							
Global		Main			Sub		
Factor	W	Factor	W	W	Factor	W	W
I. Internal	0.280	I.1	0.368	0.103	I.1.1	0.212	0.021882
					I.1.2	0.212	0.021882
					I.1.3	0.212	0.021882
					I.1.4	0.212	0.021882
					I.1.5	0.152	0.01563
		I.2	0.368	0.103	I.2.1	0.143	0.014737
					I.2.2	0.257	0.026526
					I.2.3	0.200	0.020632
					I.2.4	0.200	0.020632
					I.2.5	0.200	0.020632
		I.3	0.263	0.074	I.3.1	0.139	0.010211
					I.3.2	0.139	0.010211
					I.3.3	0.139	0.010211
					I.3.4	0.184	0.013573
					I.3.5	0.206	0.015182
					I.3.6	0.194	0.014296
E. External	0.360	E.1	0.500	0.180	E.1.1	0.333	0.06
					E.1.2	0.238	0.042857
					E.1.3	0.429	0.077143
		E.2	0.500	0.180	E.2.1	0.500	0.09
					E.2.2	0.500	0.09
F. Financial	0.360	F.1	1.000	0.360	F.1.1	0.200	0.072
					F.1.2	0.143	0.051429
					F.1.3	0.200	0.072
					F.1.4	0.257	0.092571
					F.1.5	0.200	0.072
Sum	1.000	Sum	3.000	1.000	Sum	6.000	1.000

We can get the pillars' weights and the categories' weights directly from the matrix. The summation of the global weights of factors was supposed to be equal (1) as presented in Table 5.4. The columns of zeros (sinks) in the un-weighted matrix were replaced by the same cells or columns from the identity matrix as mentioned in Chapter 2.

5.3.3 Weighted Super Matrix

After acquiring the un-weighted super matrix, the following step was transforming it in to weighted super matrix by normalizing it. The normalization process was done by getting the summation of each column and then dividing each cell within this column over the summation, obtaining a matrix; the summation of each column within it equals 1. The weighted super matrix for a sample of questionnaire is presented below in Table 5.5.

5.3.4 Limited matrix

The sinks were replaced with columns from the identity matrix and the limited matrix for the questionnaires was calculated by raising the weighted super matrix to large powers in a continuous process until one output matrix was equal to the last one before it. This limited matrix calculation process was done by raising the power of it to 256 times. The relative global weights for the factors were obtained from the first column of the limited matrix as shown in Table 5.6.

Table 5-4: Unweighted Super Matrix

Unweighted Super Matrix

	Competitiveness	Internal	External	Financial	I.1	I.2	I.3	E.1	E.2	F.1	I.1.1	I.1.2	I.1.3	I.1.4	I.1.5	I.2.1	I.2.2	I.2.3	I.2.4	I.2.5	I.3.1	I.3.2	I.3.3	I.3.4	I.3.5	I.3.6	E.1.1	E.1.2	E.1.3	E.2.1	E.2.2	F.1.1	F.1.2	F.1.3	F.1.4	F.1.5
Competitiveness	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Internal	0.280	0.000	0.438	0.438	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
External	0.360	0.500	0.000	0.563	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Financial	0.360	0.500	0.563	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1	0.000	0.368	0.000	0.000	0.000	0.583	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2	0.000	0.368	0.000	0.000	0.583	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3	0.000	0.263	0.000	0.000	0.417	0.417	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2	0.000	0.000	0.500	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F.1	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.1	0.000	0.000	0.000	0.000	0.212	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.2	0.000	0.000	0.000	0.000	0.212	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.3	0.000	0.000	0.000	0.000	0.212	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.4	0.000	0.000	0.000	0.000	0.212	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.5	0.000	0.000	0.000	0.000	0.152	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.1	0.000	0.000	0.000	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.2	0.000	0.000	0.000	0.000	0.000	0.257	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.3	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.4	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.5	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.1	0.000	0.000	0.000	0.000	0.000	0.000	0.139	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.2	0.000	0.000	0.000	0.000	0.000	0.000	0.139	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.3	0.000	0.000	0.000	0.000	0.000	0.000	0.139	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.4	0.000	0.000	0.000	0.000	0.000	0.000	0.184	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.5	0.000	0.000	0.000	0.000	0.000	0.000	0.206	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.6	0.000	0.000	0.000	0.000	0.000	0.000	0.194	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.238	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
F.1.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
F.1.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
F.1.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
F.1.4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.257	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
F.1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
Sum	1.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 5-5: Weighted Super Matrix

Weighted Super Matrix

	Competitiveness	Internal	External	Financial	I.1	I.2	I.3	E.1	E.2	F.1	I.1.1	I.1.2	I.1.3	I.1.4	I.1.5	I.2.1	I.2.2	I.2.3	I.2.4	I.2.5	I.3.1	I.3.2	I.3.3	I.3.4	I.3.5	I.3.6	E.1.1	E.1.2	E.1.3	E.2.1	E.2.2	F.1.1	F.1.2	F.1.3	F.1.4	F.1.5
Competitiveness	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Internal	0.280	0.000	0.219	0.219	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
External	0.360	0.250	0.000	0.281	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Financial	0.360	0.250	0.281	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1	0.000	0.184	0.000	0.000	0.000	0.292	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2	0.000	0.184	0.000	0.000	0.292	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3	0.000	0.132	0.000	0.000	0.208	0.208	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F.1	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.1	0.000	0.000	0.000	0.000	0.106	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.2	0.000	0.000	0.000	0.000	0.106	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.3	0.000	0.000	0.000	0.000	0.106	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.4	0.000	0.000	0.000	0.000	0.106	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.5	0.000	0.000	0.000	0.000	0.076	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.1	0.000	0.000	0.000	0.000	0.000	0.071	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.2	0.000	0.000	0.000	0.000	0.000	0.129	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.3	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.4	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.5	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.1	0.000	0.000	0.000	0.000	0.000	0.000	0.069	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.2	0.000	0.000	0.000	0.000	0.000	0.000	0.069	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.3	0.000	0.000	0.000	0.000	0.000	0.000	0.069	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.4	0.000	0.000	0.000	0.000	0.000	0.000	0.092	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.5	0.000	0.000	0.000	0.000	0.000	0.000	0.103	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.6	0.000	0.000	0.000	0.000	0.000	0.000	0.097	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.119	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.214	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
F.1.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
F.1.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.071	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
F.1.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
F.1.4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.129	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
F.1.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 5-6: Limit Matrix To The Power 256

Limit Matrix to the power 256

	Competitiveness	Internal	External	Financial	I.1	I.2	I.3	E.1	E.2	F.1	I.1.1	I.1.2	I.1.3	I.1.4	I.1.5	I.2.1	I.2.2	I.2.3	I.2.4	I.2.5	I.3.1	I.3.2	I.3.3	I.3.4	I.3.5	I.3.6	E.1.1	E.1.2	E.1.3	E.2.1	E.2.2	F.1.1	F.1.2	F.1.3	F.1.4	F.1.5
Competitiveness	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Internal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
External	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Financial	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.1	0.022	0.045	0.014	0.014	0.129	0.047	0.044	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.2	0.022	0.045	0.014	0.014	0.129	0.047	0.044	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.3	0.022	0.045	0.014	0.014	0.129	0.047	0.044	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.4	0.022	0.045	0.014	0.014	0.129	0.047	0.044	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.1.5	0.016	0.032	0.010	0.010	0.092	0.033	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.1	0.015	0.030	0.009	0.009	0.031	0.087	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.2	0.027	0.054	0.017	0.017	0.057	0.156	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.3	0.021	0.042	0.013	0.013	0.044	0.121	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.4	0.021	0.042	0.013	0.013	0.044	0.121	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.2.5	0.021	0.042	0.013	0.013	0.044	0.121	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.1	0.011	0.023	0.007	0.007	0.024	0.024	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.2	0.011	0.023	0.007	0.007	0.024	0.024	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.3	0.011	0.023	0.007	0.007	0.024	0.024	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.4	0.015	0.031	0.009	0.009	0.032	0.032	0.108	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.5	0.017	0.034	0.010	0.010	0.036	0.036	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I.3.6	0.016	0.032	0.010	0.010	0.033	0.033	0.114	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.1	0.059	0.034	0.101	0.036	0.000	0.000	0.000	0.222	0.111	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.2	0.042	0.024	0.072	0.026	0.000	0.000	0.000	0.159	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.1.3	0.076	0.044	0.130	0.046	0.000	0.000	0.000	0.286	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2.1	0.088	0.051	0.151	0.054	0.000	0.000	0.000	0.167	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
E.2.2	0.088	0.051	0.151	0.054	0.000	0.000	0.000	0.167	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
F.1.1	0.071	0.041	0.043	0.121	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
F.1.2	0.050	0.029	0.031	0.086	0.000	0.000	0.000	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
F.1.3	0.071	0.041	0.043	0.121	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
F.1.4	0.091	0.053	0.055	0.156	0.000	0.000	0.000	0.000	0.000	0.257	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
F.1.5	0.071	0.041	0.043	0.121	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

5.3.5 FANP Using Fuzzy Preference Programming Method

Several methods were developed to handle matrices of fuzzy comparison. Van Laarhoven and Pedycz proposed a least squares method of fuzzy logarithmic in obtaining the fuzzy weights by using triangular fuzzy comparison matrix. Buckley (1985) made use of the method of geometric mean in calculating the fuzzy weights. Chang (1996) also came up with an analysis method that was able to derive crisp weights that can be used in the fuzzy comparison matrices. Buckley (1996) later invented a methodology called the extent analysis. It was applied in the process of deriving crisp weights that were used in fuzzy comparison matrices. Xu (2000) designed the fuzzy method of least squares priority (LSM). Csutora and Buckley (2001) invented the lambda Max technique, which offers a direct fuzzification of the renowned method of Kmax. Later, Mikhailov (2003) came up with the method of fuzzy preference programming, which was used by practitioners in deriving fuzzy comparison matrices and used in this research to solve the FANP in determining the relative global weights.

The FPP Method was adopted in this study because of its nature of being highly effective and reasonable. It is capable of acquiring consistency ratios of the comparison matrices without the need to add Fuzzy Analytical Network Process Implementation while using the Matlab study, insinuating that the software is able to solve the local weights with ease. With respect to this study, a 9-point scale was used for the relative value of comparing pairs as demonstrated in Table 5.7.

Table 5-7: Linguistic scales for relative importance

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equally important(EI)	(1, 1, 1)	(1, 1, 1)
Intermediate1(IM1)	(1, 2, 3)	(1/3, 1/2, 1)
Moderately important(MI)	(2, 3, 4)	(1/4, 1/3, 1/2)
Intermediate2(IM2)	(3, 4, 5)	(1/5, 1/4, 1/3)
Important(I)	(4, 5, 6)	(1/6, 1/5, 1/4)
Intermediate3(IM3)	(5, 6, 7)	(1/7, 1/6, 1/5)
Very important(VI)	(6, 7, 8)	(1/8, 1/7, 1/6)
Intermediate4(IM4)	(7, 8, 9)	(1/9, 1/8, 1/7)
Absolutely important(AI)	(9, 9, 9)	(1/9, 1/9, 1/9)

There are two major steps that the Matlab software solves in FPP. The first one is the process of acquiring local weights of the comparison pairwise matrix. The second step involves calculating the limit supermatrix. The two steps are all associated with the calculation of matrices. The selection of the Matlab software was informed by its high efficiency in the course of processing and operating data. As earlier mentioned, the fuzzy comparison matrices' local weights were calculated using the FPP method. In FPP, an optimization problem is solved in which maximizing the factors weights is the objective with 0 and 1 as the lower and upper bounds. The program in our case Matlab iterates several instances to determine the global relative weights until the convergance is achieved.

It is a fact that a criteria and sub-criteria reflect different numbers, therefore their ordering in the pairwise fuzzy comparison matrix varies. Thus, matrices of different orders could be used to obtain the consistency index and local weights. Non-linear program and function definition were the first steps towards this effect. To solve the non-linear problem, the following function was created in Matlab

A=[1 1 … 1 0];

B=[1];

LB = [0; 0;…; 0; -inf];

UB = [ ];

x0 = [0.1; 0.2; …; 1];

OPT = optimset('LargeScale', 'off');

[x, fval] = fmincon('function', x0, [ ], [ ],A, B, LB, UB, 'function', OPT)

After obtaining the limited matrix, the factors global weights were obtained. The summation was checked to be equal (1). All the previous steps were carried out for all the questionnaires and the average of final global weights of all the questionnaires was obtained. The average factors global weights are shown in Figure 5.2.

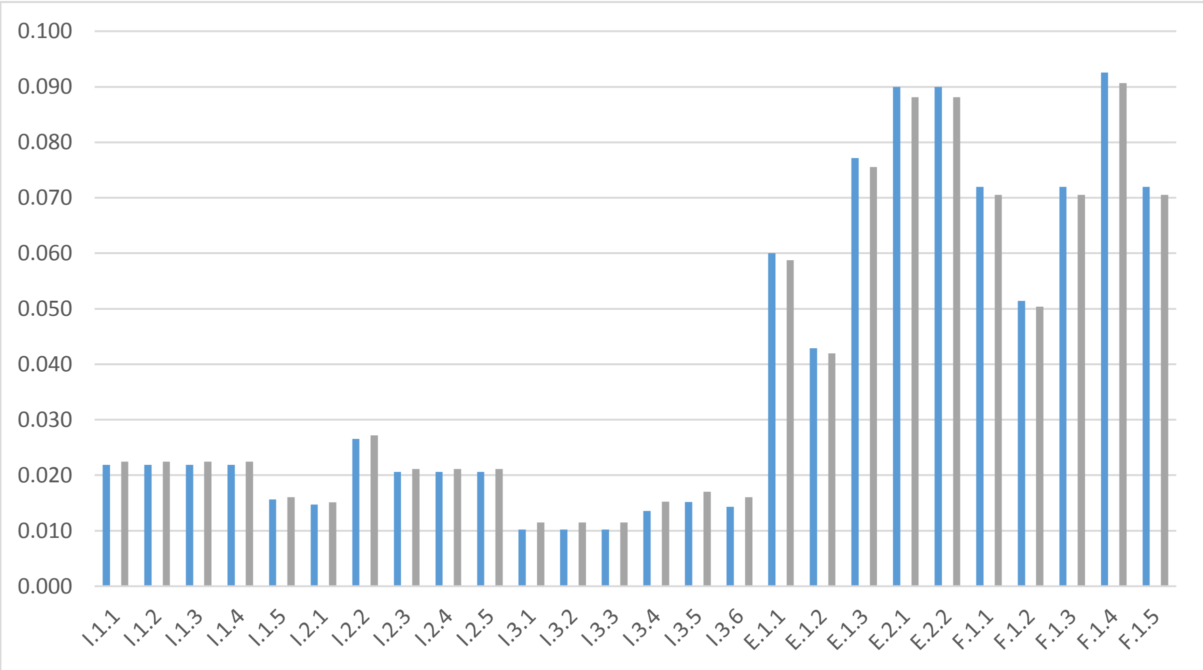


Figure 5-2: Factors Relative Weights Using ANP and FANP

With respect to global competitiveness, the element of financial resources featured as the most important, followed by external, then internal factors as shown in Figure 5.3. When it comes to the main factors, project performance scored the highest followed by organization performance, then innovation and development, as the main competitive factors in order of priority ash shown in Figure 5.4.

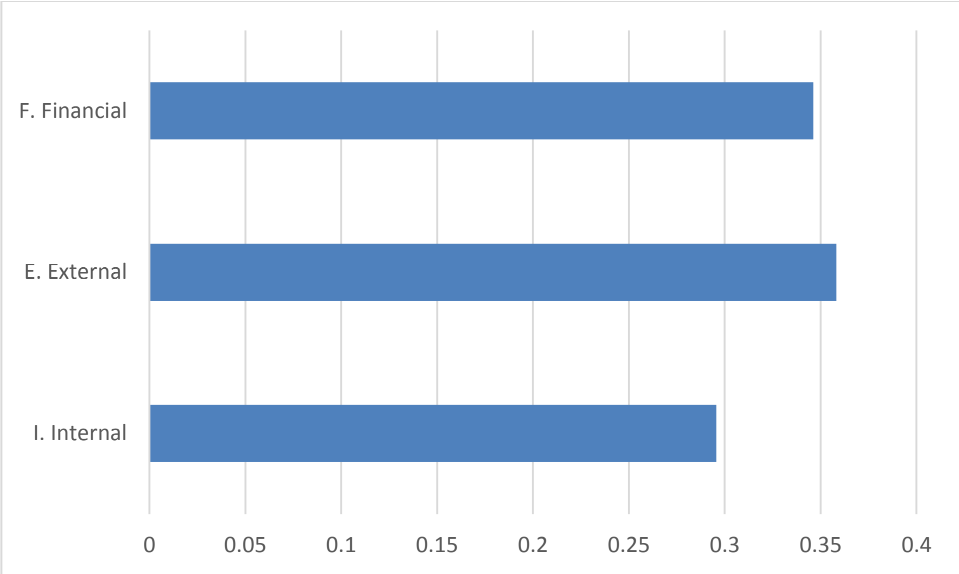


Figure 5-3: 3Ps Relative Weights

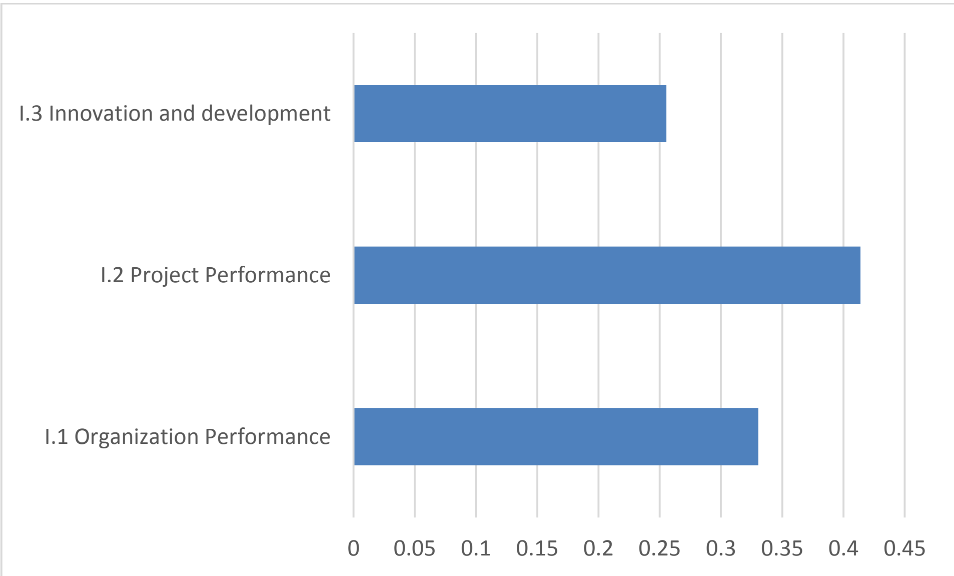


Figure 5-4: Internal Categories Relative Weights

Figure 5.5 shows that the nature of relationship which a construction company establishes with clients and industry conditions directly determines its long-term success. Other factors, such as regional economy, political aspects, and legal issues impact its performance indirectly.

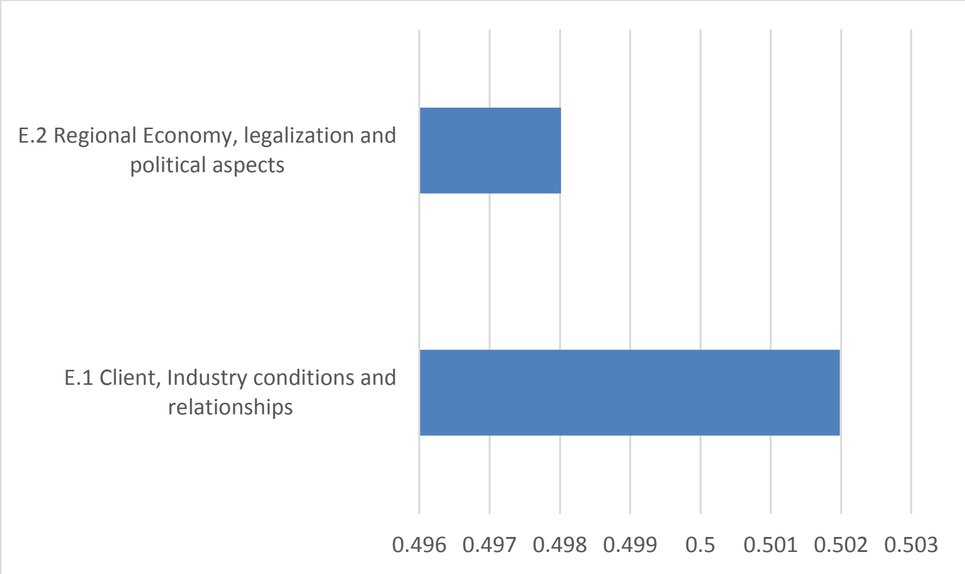


Figure 5-5: External Categories Relative Weights

With respect to main categories, the financial category featured as the most important, followed by external, then internal categories as shown in Figure 5.6.

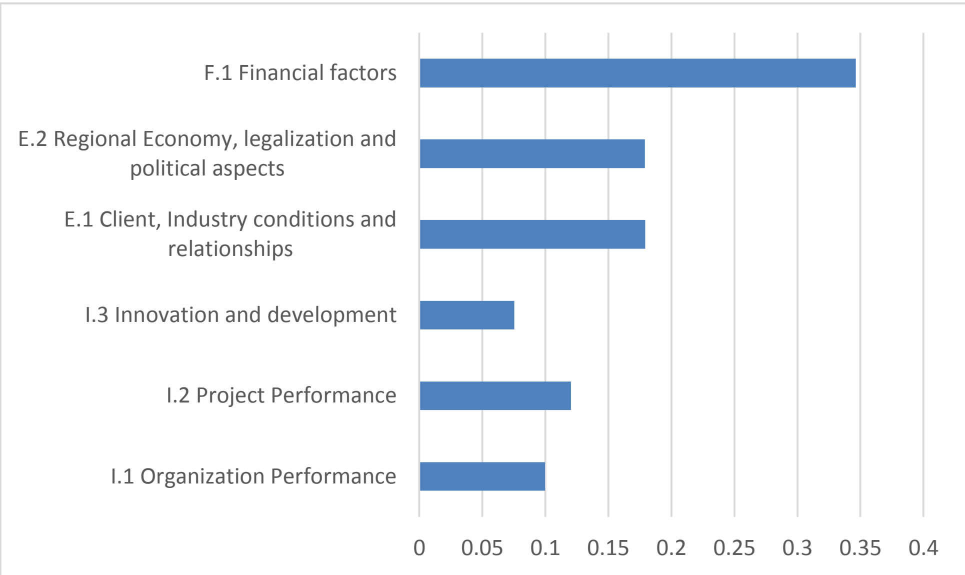


Figure 5-6: Financial Factors Weights

5.4 Functional Competitiveness Index (PROMETHEE)

The proposed model utilizes the widely used MCDM technique known as PROMETHEE in the ranking and aggregation. PROMETHEE is used to reach to the Competitiveness indices as mentioned before. The technique of FANP (Fuzzy Analytic network process) was applied in the relative calculation of the categories and factors weights. The main inputs for PROMETHEE are the weights from FANP and the assigned attribute values. As illustrated in the Chapter 3 Research Methodology. The below table 5.8 shows a sample which was applied on three companies and the ϕ net and PROMETHEE ranking was obtained.

Table 5-8: PROMETHEE Proof of Concept

Weights	Pillar 1	Pillar 2	Pillar 3	Total
Company A	0.35	0.385	0.265	1
Company B	0.325	0.31	0.365	1
Company C	0.375	0.285	0.34	1
Threshold	Pillar 1	Pillar 2	Pillar 3	
Company A	6.22	6.22	6.55	
Company B	6	6.1	6.2	
Company C	5.9	6.1	6.1	
Posedue Criteria	Pillar 1	Pillar 2	Pillar 3	
Min	0	0	0	
Max	10	10	10	
d	10	10	10	
p	1	1	1	
	PROMETHEE			
d (A1,A2)	0.22	0.12	0.35	
p (A1,A2)	0.022	0.012	0.035	
ϕ+ (A1)	0.0077	0.00462	0.009275	0.021595
d (A1,A3)	0.32	0.12	0.45	
P (A1,A3)	0.032	0.012	0.045	
ϕ+ (A1)	0.0112	0.00462	0.011925	0.027745
ϕ+ (A1) Total				0.04934
d (A2,A1)	-0.22	-0.12	-0.35	
p (A2,A1)	0.022	0.012	0.035	
ϕ- (A1)	0.00715	0.00372	0.012775	0.023645
d (A3,A1)	-0.32	-0.12	-0.45	
P (A3,A1)	0.032	0.012	0.045	
ϕ- (A1)	0.012	0.00342	0.0153	0.03072
ϕ- (A1) total				0.054365
ϕ (A1) net				-0.00503
d (A2,A1)	-0.22	-0.12	-0.35	
p (A2,A1)	0.022	0.012	0.035	
ϕ+ (A2)	0.00715	0.00372	0.012775	0.023645
d (A2,A3)	0.1	0	0.1	
p (A2,A3)	0.01	0	0.01	
ϕ+ (A2)	0.06	0	0.062	0.122
ϕ+ (A2) Total				0.145645
d (A1,A2)	0.22	0.12	0.35	
p (A1,A2)	0.022	0.012	0.035	
ϕ- (A2)	0.0077	0.00462	0.009275	0.021595
d (A3,A2)	-0.1	0	-0.1	
p (A3,A2)	0.01	0	0.01	
ϕ- (A2)	0.059	0	0.061	0.12
ϕ- (A2) Total				0.141595
ϕ (A2) net				0.00405
d (A3,A1)	-0.32	-0.12	-0.45	
p (A3,A1)	0.032	0.012	0.045	
ϕ+ (A3)	0.012	0.00342	0.0153	0.03072
d (A3,A2)	-0.1	0	-0.1	
p (A3,A2)	0.001	0	0.01	
ϕ+ (A3)	0.000375	0	0.0034	0.003775
ϕ+ (A3) Total				0.034495
d (A1,A3)	0.32	0.12	0.45	
p (A1,A3)	0.032	0.012	0.045	

ϕ- (A3)	0.0112	0.00462	0.011925	0.027745
d (A2,A3)	0.1	0	0.1	
p (A2,A3)	0.01	0	0.01	
ϕ- (A3)	0.00325	0	0.00365	0.0069
ϕ- (A3) Total				0.034645
ϕ (A3) net				-0.00015
	A	B	C	
ϕ net	-0.00503	0.00405	-0.00015	
CI (0-10)	5.025125	4.97975	5.00075	
PROMETHEE Ranking	1	3	2	

5.5 Summary

In this chapter the different methods and concepts used in developing the construction company's competitiveness index was presented. PROMETHEE and FANP were introduced in addition to the different factors affecting company's competitiveness.

CHAPTER 6: MODEL IMPLEMENTATION AND CASE STUDIES

6.1 Introduction

To validate the proposed model, there were a total of five case studies, used to examine the accuracy of the model of competitiveness index. The weights of the factors were based on data gathered from international companies in the construction industry. There were two types of information that were applied in operating the model which were subjective and statistical data. Complete data sets were sourced from 5 construction companies. Table 6.1 illustrates the different values from the 5 companies. This section will offer a discussion of the deductions that were acquired from the case studies.

Table 6-1: Data Collected for the five Case Studies

Factor	Minimum Threshold	Maximum Threshold	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Case Study 5
I.1.1 Human and Knowledge	75000	175000	16313	14517	16494	83228	15060
I.1.2 Company resources	1	5	5	3	1	3	5
I.1.3 Bidding	34	66	39	41	35	63	62
I.1.4 Competitive strategy	1	5	4	3	2	4	2
I.1.5 Organization structure	3	5	4	4	4	4	4
I.2.1 Time	0.775	1.1	1	1	1	1	1
I.2.2 Cost	0.838	1.038	1	1	1	1	1
I.2.3 Quality	0	5	1	1	0	5	3
I.2.4 health and safety	0.75	10.75	10	6	10	1	8
I.2.5 Other project management systems	3	5	5	3	5	4	5
I.3.1 Marketing	5.8	23.6	23	11	11	16	23
I.3.2 Technology abilities	4.75	12.5	8	10	8	10	5
I.3.3 Adjust Oneself ability	14	41	18	41	32	29	26
I.3.4 Human resources development & learning	2100	5200	4478	2796	5116	3872	2698
I.3.5 Research and development ability	2.4	11	10	4	8	4	8
I.3.6 Companies adaptation to new environments	3	5	5	3	4	5	5
E.1.1 Client	3	5	4	3	5	5	5
E.1.2 Industry conditions	3	5	4	3	5	3	4
E.1.3 Relationships	3	5	5	3	4	5	4
E.2.1 Economical Factors	$32*10^{18}$	$83*10^{18}$	$76*10^{18}$	$51*10^{18}$	$62*10^{18}$	$58*10^{18}$	$80*10^{18}$
E.2.2 Legalization and political aspects	0.36	0.86	1	1	1	1	1
F.1.1 Profit Margin Ratio	9.2	20.6	11	17	17	10	18
F.1.2 Activity Ratio	11.28	39.36	15	36	19	26	18
F.1.3 Leverage ratio	4.56	34.82	27	13	9	29	34
F.1.4 Liquidity Ratio	12.26	32.33	27	28	24	32	29
F.1.5 Growth Ratio	15.65	30.78	28	28	27	23	21

6.2 Case Study 1

Company 1 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. Two experts offered information concerning Company's 1 competitive score which was 8. The other expert estimated a competitive value of 4. This means that the company's average competitive score was (8+8+4)/3= 6. The proposed model calculated Company's 1 competitiveness index of a value of 6.25. Pillar's score for the company were calculated and later used to construct Figure 6.1 and Figure 6.2.

Figure 6.1 shows the distribution of the relative weights for the different factors for case study 1 company. As illustrated in the figure, cost and time had the highest share in the company's internal factors with a value of 0.069 (approximately 7%), whereas factor "adjust one's ability" had the lowest share of a value of 0.008 (less than 1%). One can conclude from such information that this organization pay more attention to time and cost when bidding. Regarding the company's external factors "Adaptation to new environments" had the highest share of a value of 0.063 (6.5%) which indicates that such organization is capable of bidding to new projects that are not conventional to the organization. On the other hand "client" factor recorded the lowest relative weight when compared to the rest of the external factors, which seem logical due to the extra care given to cost that could affect the relations with the client. Financially "liquidity ratio" had the highest relative weights of a value of 0.056 and leverage ratio of a value of 0.008.

Figure 6.2 shows that the relative weights of external and financial factors are divided equally with a value of 0.4, whereas the internal factors relative weights has the lowest relative weight of 0.2. It can be anticipated from such figure that the company's competitiveness index would be higher than other companies because the company's external relations and financial welfare are important than the company's internal factors.

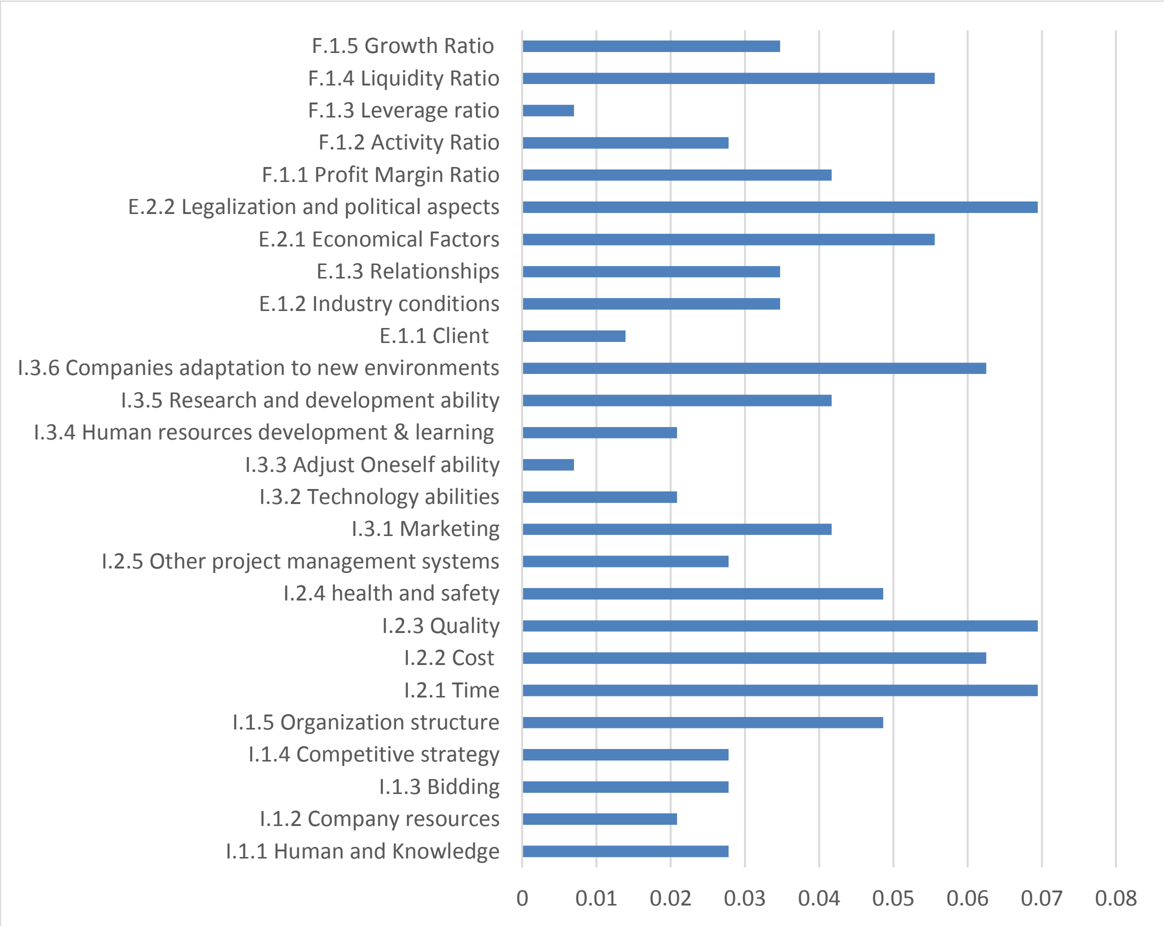


Figure 6-1*:* Relative Weights Distribution for Factors (Case Study 1)

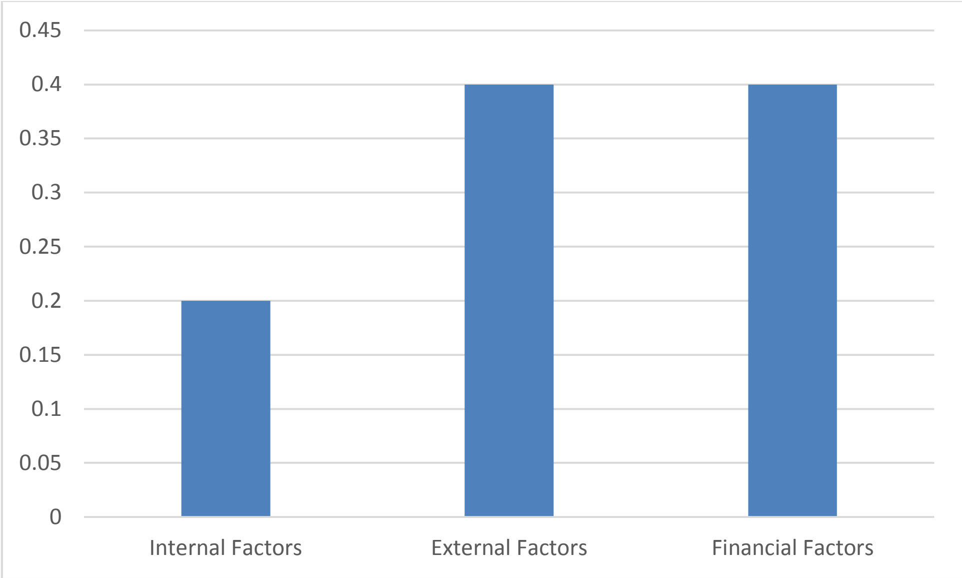


Figure 6-2: Relative Weights Distribution for Main Pillars (Case Study 1)

6.3 Case Study 2

Company 2 is a privately owned firm situated in Cairo, Egypt and started operations in 1982. Its experience record include 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 gauged its competitive ability. The first expert gave it a value of 4 and the other 6. Thus the average score is 5. The proposed model calculated Company 2 competitiveness index that is 5.5. Pillar's score for the company were calculated and later used to construct Figure 6.3 and Figure 6.4

Figure 6.3 shows the distribution of the relative weights for the different factors for case study 2 company. As illustrated in the figure, Cost had the highest share in the company's internal factors with a value of 0.078 (approximately 8%), whereas factor "Quality" had the lowest share of a value of 0.008 (less than 1%). One can conclude from such information that this organization pay more attention to cost when bidding. Regarding the company's external factors "Economical factors" had the highest share of a value of 0.075 (7.5%) which indicates that such organization is capable of well predicting and forecasting the factors regarding forecasting the economy that are not conventional to the organization. On the other hand "Industrial Conditions" factor recorded the lowest relative weight when compared to the rest of the external factors. Financially "Activity ratio" had the highest relative weights of a value of 0.061 (6.1%) and leverage ratio of a value of 0.008(0.8%).

Figure 6.4 shows that the relative weights of External and Internal factors are divided equally with a value of 0.3, whereas the internal factors relative weights has the highest relative weight of 0.4. It can be anticipated from such figure that the company's financial welfare are important than the company's internal factors and external relations.

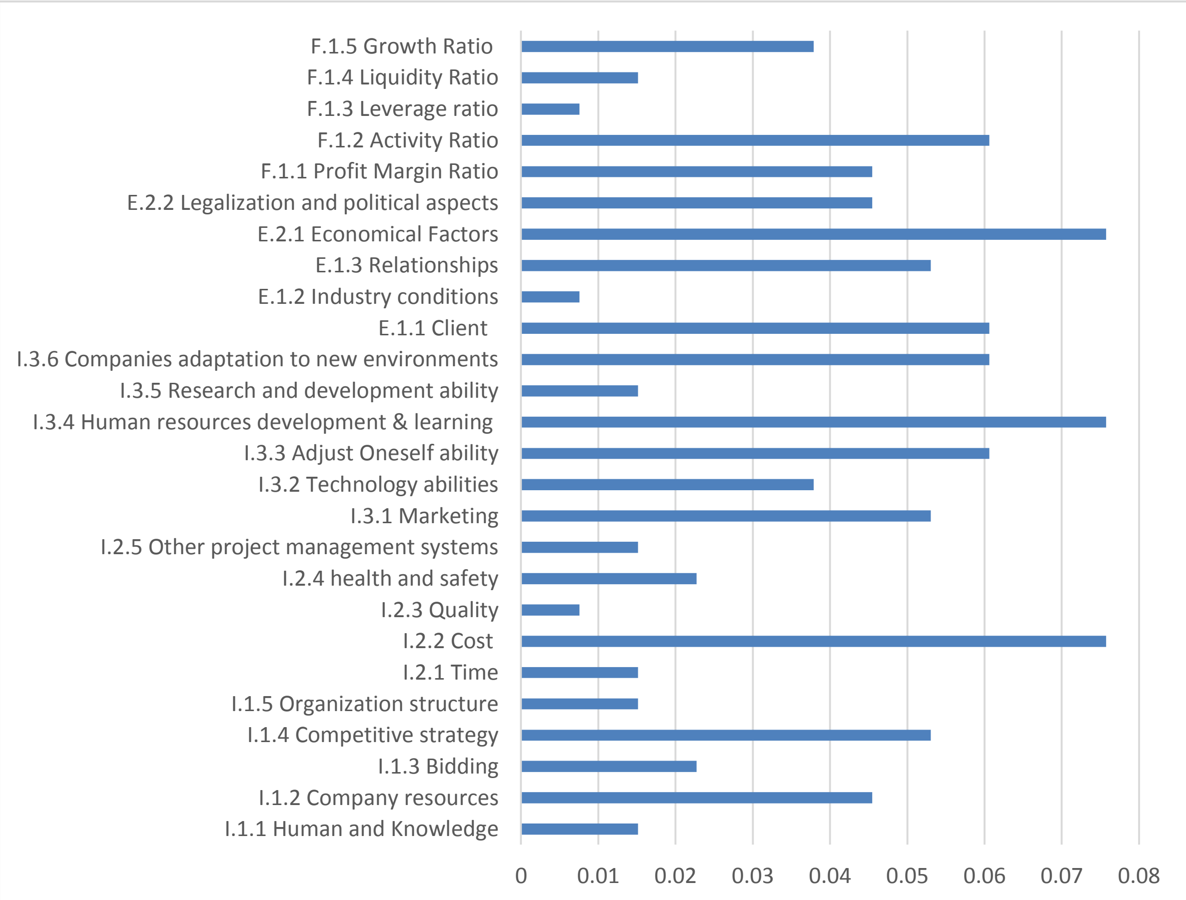


Figure 6-3: Relative Weights Distribution for Factors (Case Study 2)

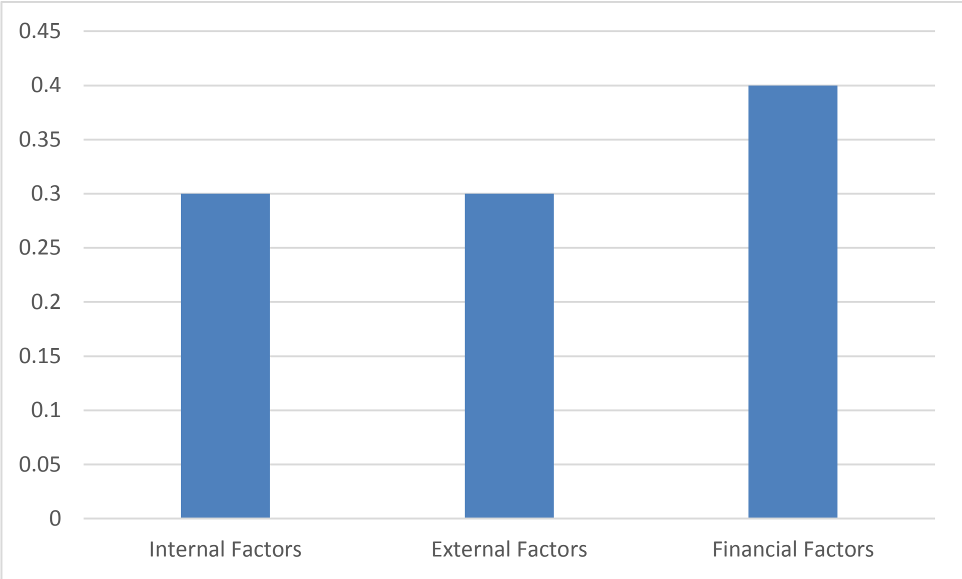


Figure 6-4: Relative Weights Distribution for Main Pillars (Case Study 2)

6.4 Case Study 3

This company features 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. Three experts filled the survey form of Company 3. The data about the company were provided by an expert representing the company with. The expert offered information concerning Company 3's competitive score which was 7. The proposed model calculated Company 3 competitiveness index that is 6. Pillar's score for the company were calculated and later used to construct Figure 6.5 and Figure 6.6.

Figure 6.5 shows the distribution of the relative weights for the different factors for case study 3 company. As illustrated in the figure, "Time", "adjust one's ability" and "Quality" had the highest share in the company's internal factors with a value of 0.067 (approximately 7%), whereas factor "Human and knowledge" had the lowest share of a value of 0.0075 (less than 1%). One can conclude from such information that this organization pay more attention to time and Quality when bidding. Regarding the company's external factors "Industrial Conditions" had the highest share of a value of 0.075 (7.5%) which indicates that such organization is paying a lot of attention to the conditions of the industry during bidding to new projects that are not conventional to the organization. On the other hand "Relationships" factor recorded the lowest relative weight when compared to the rest of the external factors. Financially "Growth ratio" had the highest relative weights of a value of 0.083(8.3%) and leverage ratio of a value of 0.008(0.8%).

Figure 6.6 shows that the financial factor has the highest relative weight value of 0.5, whereas the internal factors relative weights has the lowest relative weight of 0.2. It can be anticipated from such figure that the company's financial welfare are important than the company's Internal and External factors

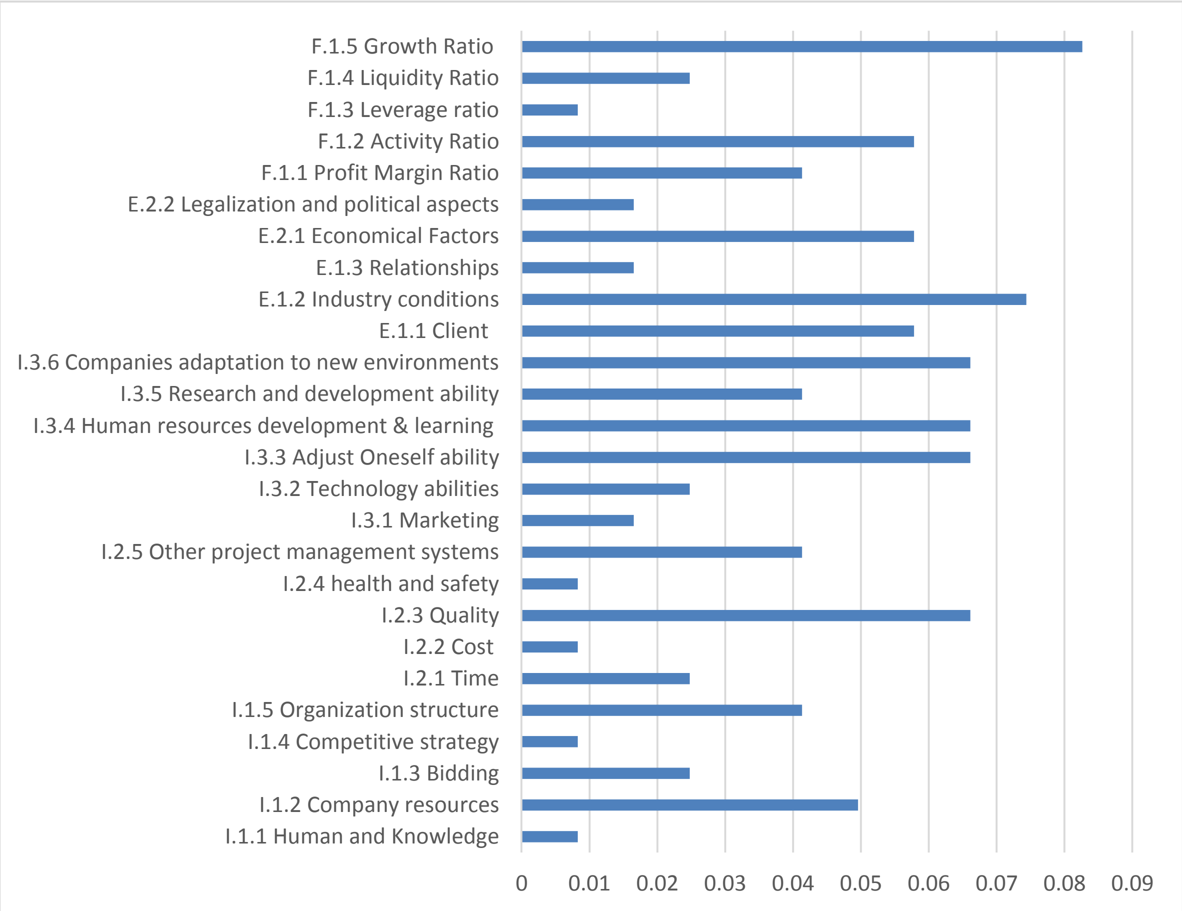


Figure 6-5: Relative Weights Distribution for Factors (Case Study 3)

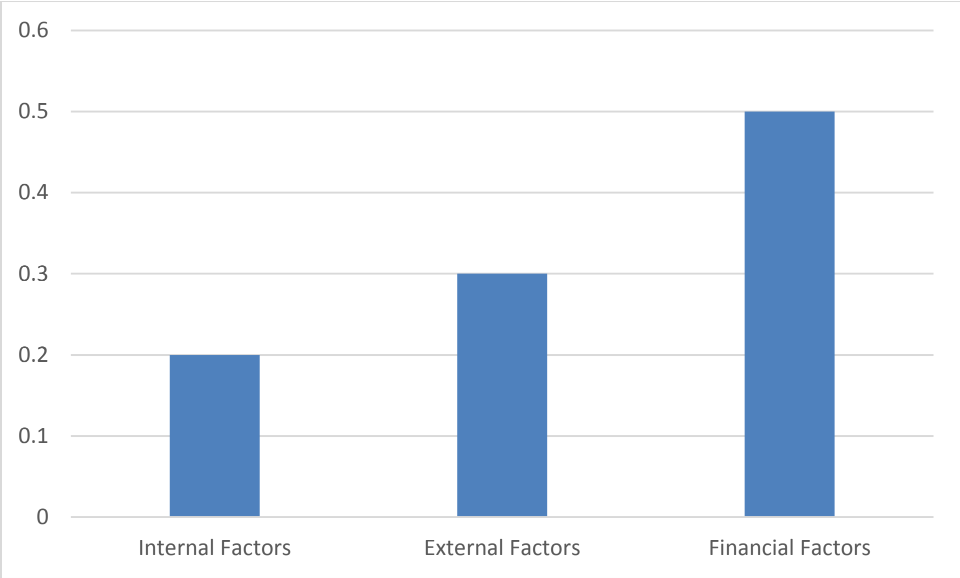


Figure 6-6: Relative Weights Distribution for Main Pillars (Case Study 3)

6.5 Case Study 4

This is a big private construction firm in Vietnam. Established in 1997, the company has vast experience in the sector of construction it deals with 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 expert offered information concerning Company 4's competitive score which was 5. The proposed model calculated Company 4 competitiveness index that is 2.3. Pillar's score for the company were calculated and later used to construct Figure 6.7 and Figure 6.8.

Figure 6.7 shows the distribution of the relative weights for the different factors for case study 4 company. As illustrated in the figure, "Quality", "Health & Safety" and "Project management Systems" had the highest share in the company's internal factors with a value of 0.064 (approximately 6.4%), whereas factor "Competitive Strategy" had the lowest share of a value of 0.065 (less than 1%). One can conclude from such information that this organization pay more attention to Quality and Health & Safety when bidding. Regarding the company's external factors "Client" and "Economical factors" had the highest share of a value of 0.064 (6.4%). On the other hand "Relationships" factor recorded the lowest relative weight (1.9%) when compared to the rest of the external factors. Financially "liquidity ratio" had the highest relative weights of a value of 0.064 (6.4%) and leverage ratio of a value of 0.0064 (0.64%).

Figure 6.8 shows that the relative weights of external has the highest relative weight value of 0.7, whereas the Financial factors relative weights has the lowest relative weight of 0.1. It can be anticipated from such figure that the company's competitiveness index would be lower than other companies because the company's external relations welfare are important than the company's financial factors.

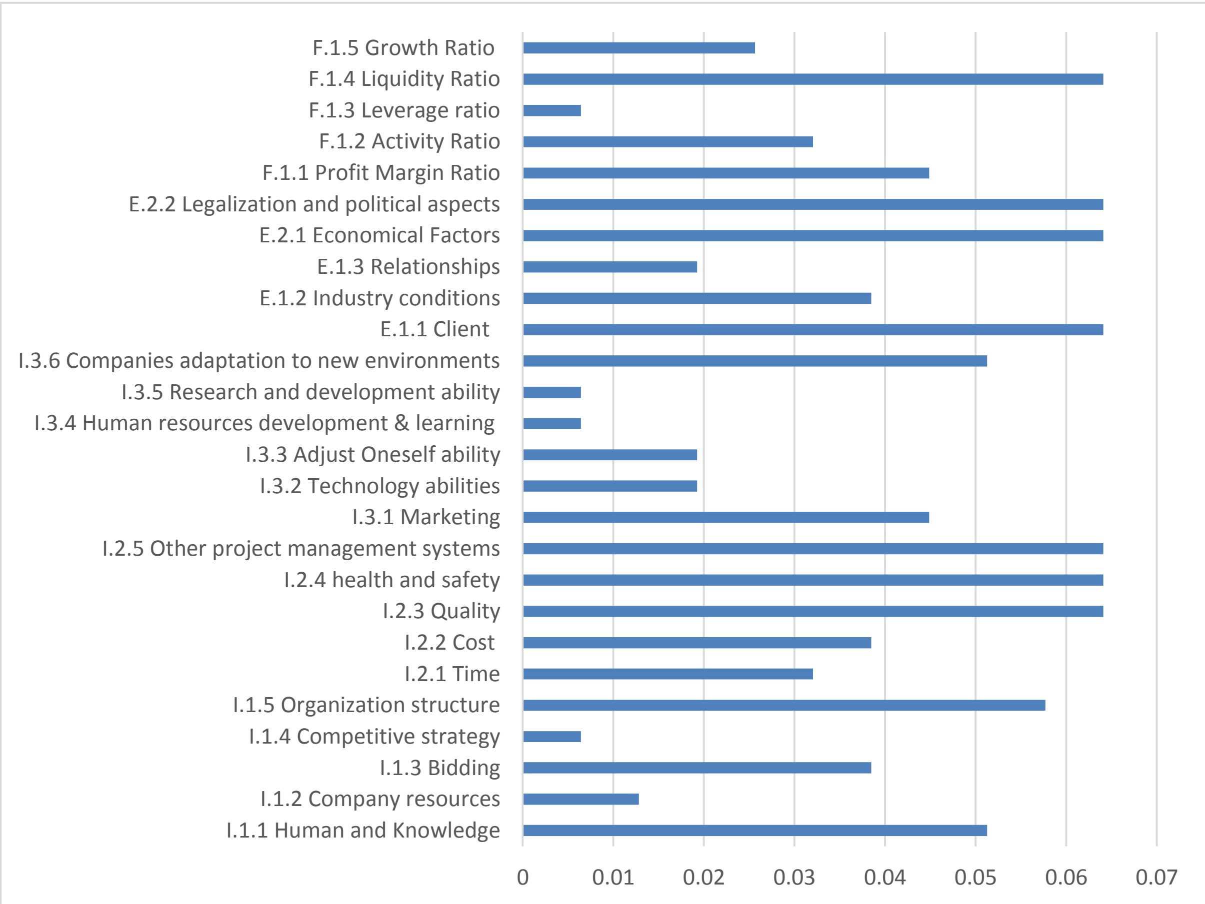


Figure 6-7: Relative Weights Distribution for Factors (Case Study 4)

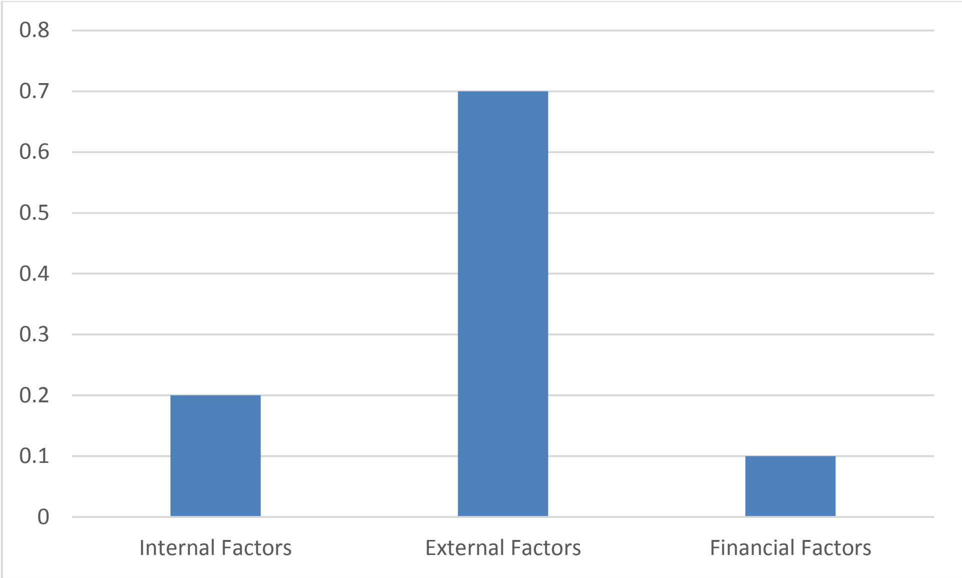


Figure 6-8: Relative Weights Distribution for Main Pillars (Case Study 4)

6.6 Case Study 5

Company 5 is a firm that is based UK, and was started in 1999. Some of its past performance portfolio includes a variety of international projects, such as Roads, infrastructure 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 others experts. Experts offered information concerning Company 5's competitive score which was 8. The other expert arrived at a competitive value of 10. This means that the company's average competitive score was (8+10)/2= 9. The proposed model calculated Company 5 competitiveness index that is 8.23. Pillar's score for the company were calculated and later used to construct Figure 6.9 and Figure 6.10

Figure 6.9 shows the distribution of the relative weights for the different factors for case study 5 company. As illustrated in the figure, "Cost", "Organization structure" and " Company Resources" had the highest share in the company's internal factors with a value of 0.057 (5.7%), whereas factor "Time" had the lowest share of a value of 0.0063 (less than 1%). One can conclude from such information that this organization pay more attention to cost when bidding. Regarding the company's external factors "Industry Conditions" had the highest share of a value of 0.057 (5.7%). On the other hand "Adaptation to new environments" factor recorded the lowest relative weight when compared to the rest of the external factors. Financially "Growth ratio" had the highest relative weights of a value of 0.063(6.3%) and Profit margin ratio of a value of 0.0063(0.63%).

Figure 6.10 shows that the relative weights of financial factors has the highest relative weights value of 0.5, whereas the external factors relative weights has the lowest relative weight of 0.1. It can be anticipated from such figure that the company's competitiveness index would be higher than other companies because the company's financial welfare are important than the company's external factors.

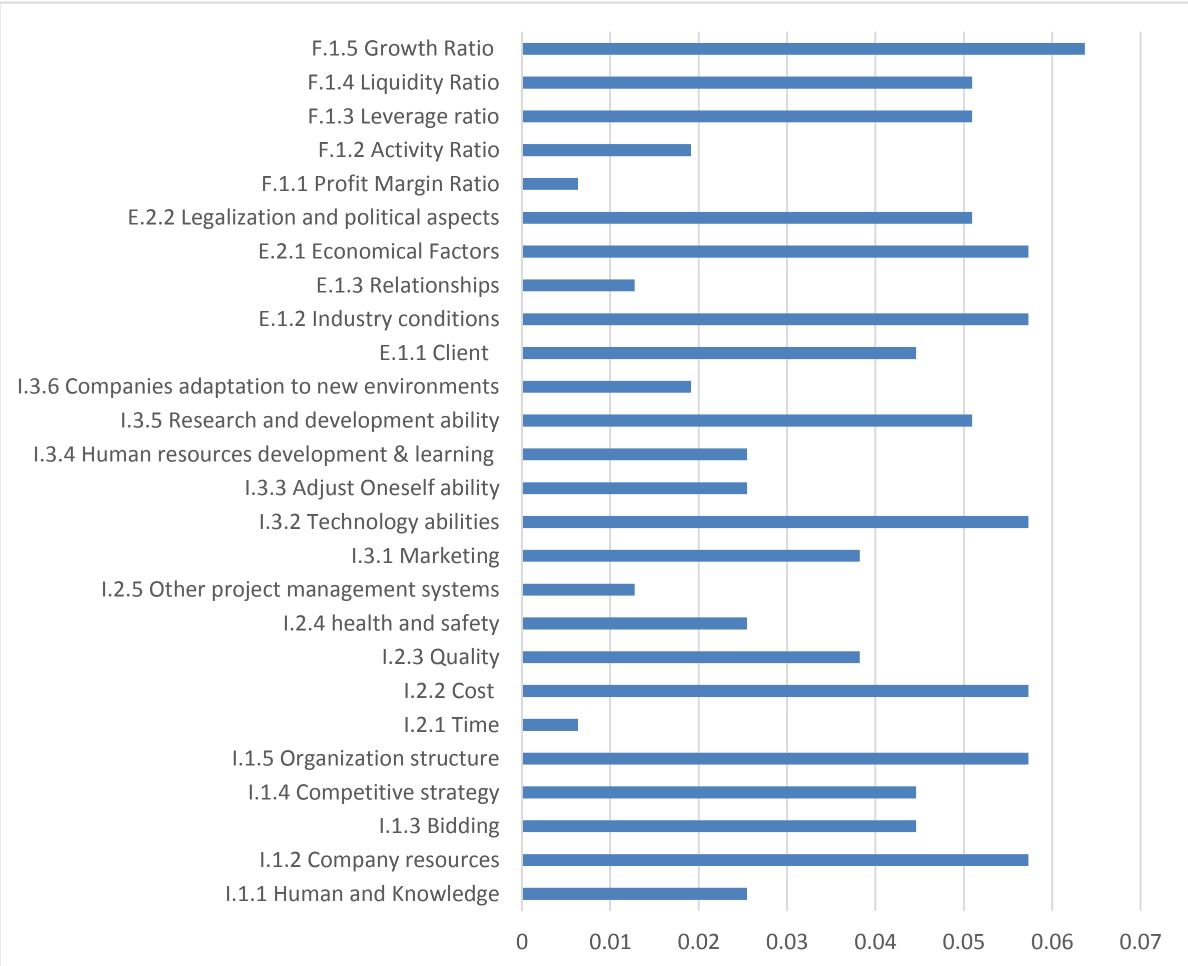


Figure 6-9: Relative Weights Distribution for Factors (Case Study 5)

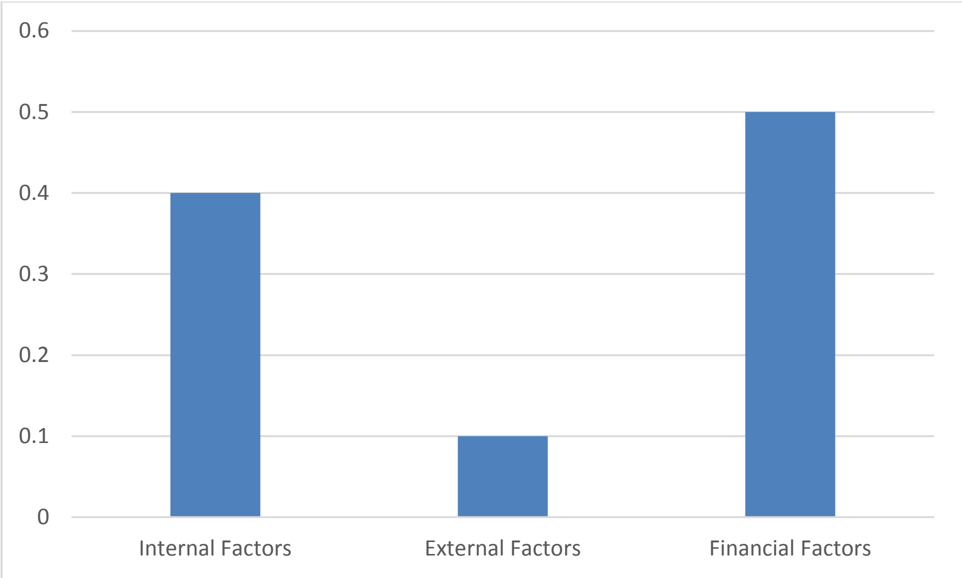


Figure 6-10: Relative Weights Distribution for Main Pillars (Case Study 5)

6.7 Model Validation

Results of the model were validated using the technique of comparison between the index of calculated competitiveness and the estimation that was offered by experts by the proposed model. The competitiveness input of experts was attained by conducting surveys as demonstrated in the case studies. This was done by asking experts to gauge the competitiveness value of the construction company. On the other hand, the model was used to gauge the competitiveness of the companies in an initiative that ran parallel to the task of the experts. PROMOTHEE was utilized to do the competitiveness index calculations. Going by the previous percentage values, the model of competitiveness evaluation could be used for a global construction sectors.

6.8 Sensitivity Analysis

The weights of the criteria and weight factors were calculated by relying on the opinions of the experts. Consequently, the sensitivity analysis featured while determining whether there are any effects in changing the criteria’s weights on the index of competitiveness. The steps used to perform the sensitivity analysis are described below.

1. Changing the criterion's original weight, the difference between modified D and the original weights.W_i -30%; W_i-20%; W_i-10%; W_i+10%; W_i+20%; W_i+30%.
2. For each percentage weight, determine the difference in the modified and original weights.

The analysis was undertaken solely for three factors that reflect the highest weight in each pillar. Due to the fact that companies' criteria weight was different from each other, there was an obligation to conduct a sensitivity analyses. The case scenarios that are generated and later plotted as demonstrated in by the Figure 6-11. The figure offer evidence to the fact that "Liquidity Ratio" is one of the most sensitive factor that construction companies can apply. As such, changes in a single factor automatically insinuates corresponding changes in the index of competitiveness.

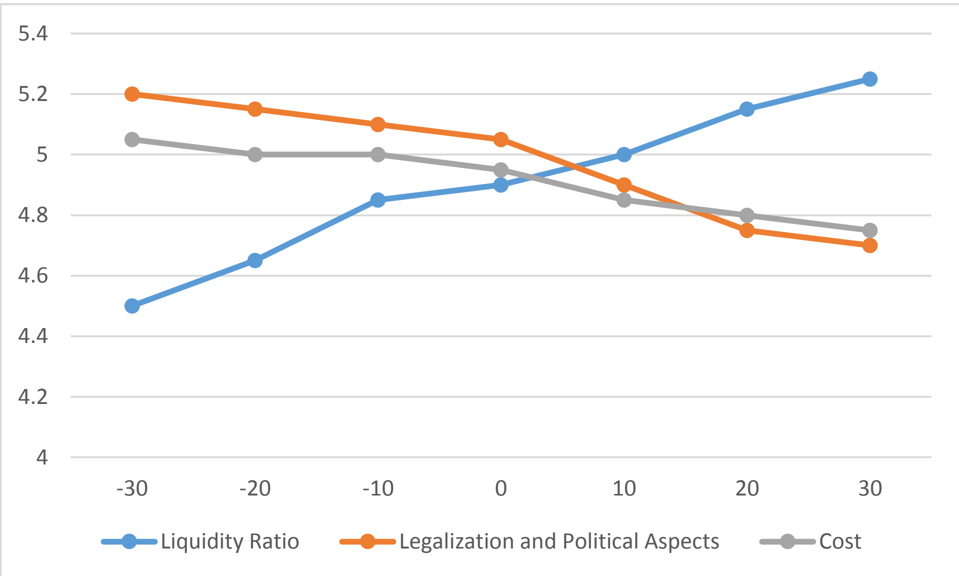


Figure 6-11: Sensitivity Analysis Results

6.9 Analysis of Results and Discussion

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 special emphasis on some factors, such as organization performance, project performance, client and environmental, innovation and organizational development. One of the benefits of applying the 3P model is that there is a detailed analysis of a series of competitive factor, such as the fact that it is very vital to build valuable relationships with customers.

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 equipment 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 see to it that more attention features in the need for projects to realize the expected value. It is a wide process that comprises co-creation initiatives with stakeholders, especially the clients.

6.10 Competitive Index for Construction Companies Calculator (CICCC)

To facilitate the input and visualizing the output, a graphical user interface was developed using Matlab. Figure 6.12 shows the welcome window from which the user can insert the weights of criteria and number of factors.

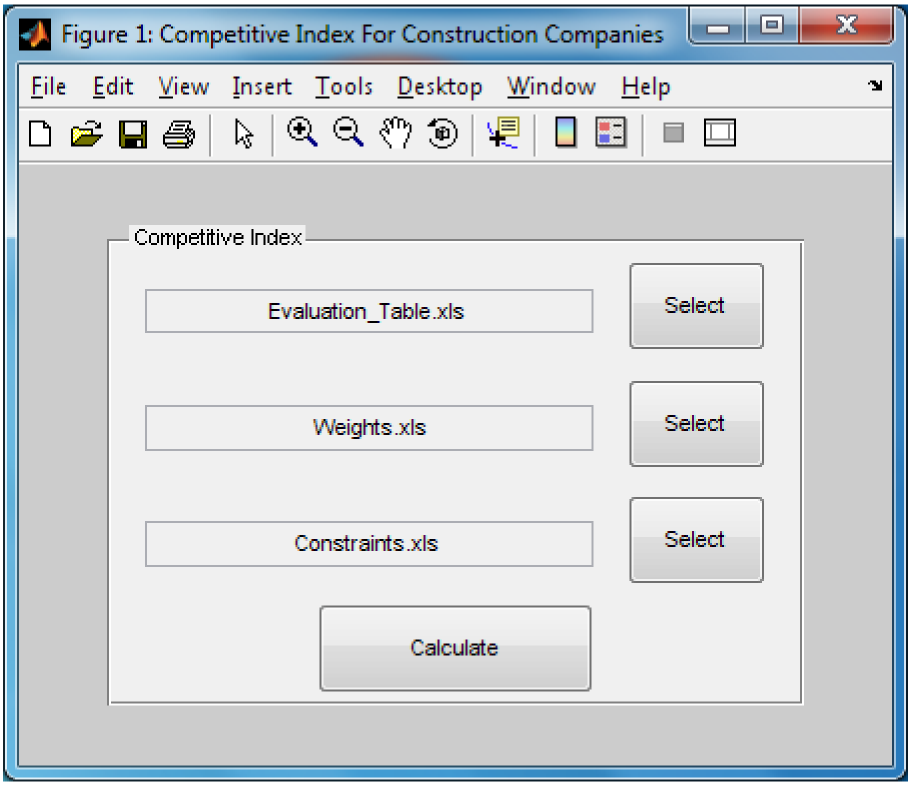


Figure 6-12: CICCC - Welcome Window

Figure 6.13 shows the output of the Matlab from which the user can visualize the competitiveness index of each company. Additionally the developed tool can provide the user with a table for the different competitiveness indices.

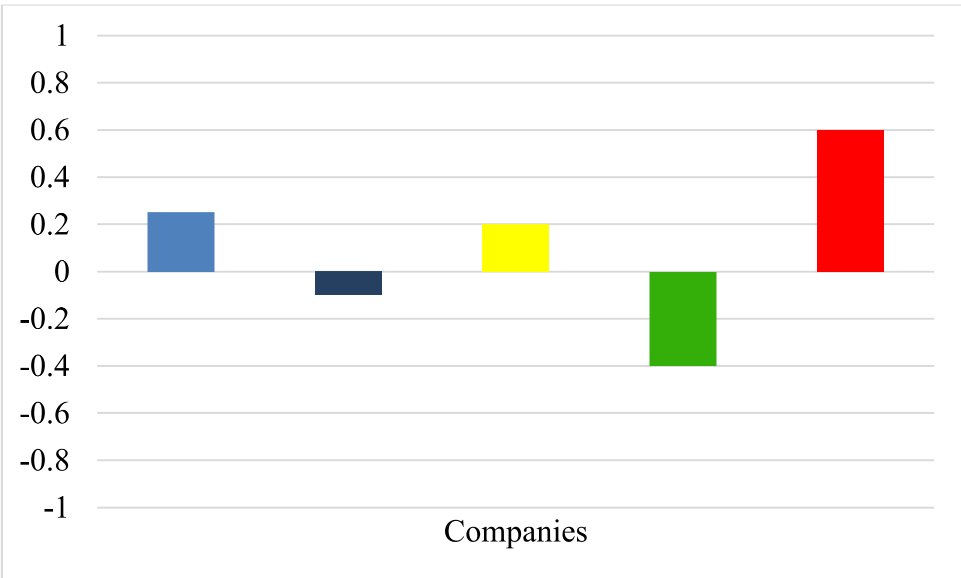


Figure 6-13: CICCC Output

Table 6-2: CICCC – Competitiveness Indices

Company	Φ	Competitive Index
Company 1	0.25	6.25
Company 2	-0.1	5.5
Company 3	0.2	6.01
Company 4	-0.4	2.3
Company 5	0.6	8.23

6.11 Summary

The chapter focused on exploring the set of processes that ensure while pursuing competitiveness of construction firms. There are two information sets that guide the model, including factors utility and factors weight values. The section also evaluated a series of competitive findings that were acquired from a survey that comprised experts in the field of construction. The case studies offered meaningful insight into the relative importance of factors and their corresponding utility functions. There was establishment of a PROMETHEE model in calculating the competitive scores of the case study companies. This chapter's second part offers explanation of the case study companies in which the model's predication accuracy was compared to actual values and showed plausible results.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

This research presented the main challenges that construction companies face with respect to measuring their competitiveness. The analysis has demonstrated that the constant technological changes compel companies to adapt new techniques and methodologies as a way of updating themselves with external changes. In this light, the competitiveness evaluation model presented in this research highly considers challenges that presently exist in the market. The provisions of the model were acquired from interview with experts and literature review. This research introduced three new pillars (3Ps) with some essential factors that affect the competitiveness of construction companies. This research addressed the present challenges facing the construction industry and classified these factors.

7.2 Research Contributions

The main objective of this study was to develop a competitiveness evaluation model for construction companies. The sub-objectives include:

- Identify and study financial and non-financial factors for competitiveness of construction companies.
- Develop a model to determine the competitiveness index of construction companies.
- Develop a dynamic user's interface for companies competitiveness evaluation "Construction Companies Competiveness Index Calculator (CCCIC)"

In line with the above there are certain contributions which could be concluded from this research and can be summarized as follows:

- Generalize competitiveness index for construction companies.

- Reduce subjectivity and uncertainty when identifying performance evaluation functions using PROMETHEE.
- Gathering data from several companies which will benefit in reducing the uncertainty and leading to more realistic results.

7.3 Research Limitations

- The developed questionnaire was considered difficult for respondents with respect to evaluating the inputs required for the thresholds.
- The collected questionnaires responses were 20 questionnaires, with a response rate of 40%. More responses are required for more accurate results.
- FANP weights were subject to expert surveys that are numerically limited and the research survey were not conducted for all countries worldwide.
- The developed model was subject to the collected questionnaires. Thus, highly sensitive to the inputs and counts of the collected questionnaires.

7.4 Recommendations and Future Work

Further research can be carried out in future work that can enhance the current work as follows:

- Future research should apply the Three Pillars to construction organizations and present more case studies.
- Future research should utilize the concept and the model with a focus on a specific construction industry size and type.
- Incorporating more historical data into the implemented case studies for a more precise judgment about the model.
- Gathering more questionnaires from different locations.
- To develop a more accurate competitiveness index, future research should conduct more in-depth construction company surveys.

- Using other techniques to determine the competitiveness index and MCDM techniques to determine the relative weights of the factor affecting the competitiveness in the construction companies.

REFERENCES

Abraham G. (2000). Identification of critical success factors for construction organization in the architectural/engineering/construction industry. Ph.D. thesis, Georgia Institute of technology.

Akyuz, E., Hristos K., and Metin C. (2015). Assessment of the maritime labour convention compliance using balanced scorecard and analytic hierarchy process approach. Maritime Policy & Management 42.2: 145-162.

Barney, J. (1991). Firm resources and sustained competitive advantage. J. Manage., 17(1), 99–120.

Barney, J. B. (1995). Looking inside for competitive advantage. Academy of Management Executive, 9(4), 49-61.

Barney, J. B. (2001). Resource-based theories of competitive advantage: a ten-year retrospective on the resource-based view. Journal of Management, 27(6), 643-650.

Bassioni, H.A et al (2005) Building a conceptual framework for measuring business performance in construction: an empirical evaluation. Construction Management & Economics, 23: 495-507.

Bassioni, H.,A, Price, A.D.F, Hassan, T.M, (2004).Performance Measurement in Construction. Journal of Management in Engineering. 42-50.

Betts, M. and Ofori, G. (1994).Strategic planning for competitive advantage in construction: the institutions. Construction Management and Economics, 12(6), 203–17.

Betts, M., and Ofori, G. (1992). Strategic planning for competitive advantage in construction. Constr. Manage. Economics, 10(6), 511–532.

Buckley, J., & Pervez N.(2015). International Business Strategy: Theory and Practice. New York: Routledge.

Chinowsky, P. (2001). Strategic Management in Engineering Organizations. Journal of Management in Engineering, ASCE, 17(2), 60-68.

Chinowsky, P. S., Meredith, J. E. (2000). Strategic management in construction. Journal of Construction Engineering and Management, 126(1), 1-9.

Dess G. et al. (2013). Strategic Management: Text and Cases", McGraw-Hill .

Elwakil et al. (2009).Investigation and modeling of critical success factors in construction organization. Construction Research Congress.

Flanagan, R..Ericsson, S. and Henricsson, J.P.E. (2005).Measuring Construction Competitiveness in Selected Countries, Final Report, School of

Construction Management and Engineering, the University of Reading.

Flanagan, R., Lu, W. S., Shen, L. Y., and Jewell, C. A. (2007). Competitiveness in construction: A critical review of research. Constr. Manage. Economics, 25(9), 989–1000.

Flanagan, R. (2005).Moving from construction productivity to construction competitiveness: Measuring value not output.

Francisco A. Orozco, Alfredo F. Serpell, Keith R. Molenaar and Eric Forcael (2013). Modeling Competitiveness Factors and Indexes for Construction Companies: Findings of Chile. ASCE

Friedman, L. (1956) A competitive bidding strategy. Operations Research, 1(4), 104–12.

Hamel, G., and Prahalad, C. K. (1994). Competing for the future, Harvard Business Books, Boston.

Ive, G., Gruneberg, S., Meikle, J. and Crosthwaite, D. (2004).Measuring the Competitiveness of the UK Construction Industry", Vol. 1 and Vol. 2, Department of Trade and Industry (DTI), London.

Kagioglou, M., Cooper, R., and Aouad, G. (2001). Performance management in construction: A conceptual framework. Constr. Manage. Economics, 19(1), 85–95.

Kaplan, R. S., and Norton, D. P. (1996). Using the balanced scorecard as a strategic management system. Harvard Bus. Rev., 74(1), 75–85.

Kaplan, R. S., and Norton, D. P. (2000). Having trouble with your strategy? Thenmap it. Harvard Bus. Rev., September-October.

Kerzner, H.,R. Project Management: A Systems Approach To Planning, Scheduling, And Controlling. John Wiley & Sons, 2013.

Kumar, A, Motwani, J, Douglas, C, (1999) "A quality competitiveness index for benchmarking", Benchmarking: An International Journal, Vol. 6 No. 1, 1999, 12-21.

Ling F.Y,& Gui,Y.(2009). Strengths, Weaknesses, Opportunities, and Threats: Case Study of Consulting Firms in Shenzhen, China. Journal of Construction Engineering and Management, ASCE. 135 (7): 628-636.

Long D., N. (2004).A case study on project success factors in large construction projects in Vietnam. Eng, Construc Achitect Manage.

Lu, W. S., Shen, L. Y, Yam, C. H. M. (2008). Critical Success Factors for Competitiveness of Contractors: China study. Journal of Construction Engineering an d Management, ASCE, 132(12), 972-982.

Luqman, O.,O.,, Abimbola O., & Keith S., Cl. (2014). Competitiveness of construction organisations in South Africa. Construction Research Congress, ASCE.

Mazri I.A (2005).Critical success factors for the construction organization. University Technology, Malaysia.

Metri B.A (2005).TQM Critical Success Factors For Construction Firms. Management, Vol. 10, 2005, 2, pp. 61-72.

Momaya, K. and Selby, K. (1998) International competitiveness of the Canadian construction industry: a comparison with Japan and the United States. Canadian Journal of Civil Engineering, 25, 640–52.

Moselhi, O., Hegazy, T., and Fazio, P. (1993). DBID: Analogy-based DSS for bidding in construction. Journal of Construction Engineering and Management, ASCE,119(3), 466-479.

Ngowi, A. B. (2001). “Creating competitive advantage by using environment-friendly building processes.” Build. Environ., 36(3), 291–298.

Ngowi, A. B., Pienaar, E., Talukhaba, A., and Mbachu, J. (2005). The globalization of the construction industry—A review. Build. Environ., 40(1), 135–141.

Ofori, G(2003) “Frameworks for analyzing international construction”. Journal of Construction management and Economics, 21(June), 379-391.

Orozco, Francisco A., et al. "Modeling competitiveness factors and indexes for construction companies: Findings of Chile." Journal of Construction Engineering and Management 140.4 (2014): B4013002.

Oz, O. (2001) “Sources of competitive advantage of Turkish construction companies in international markets”. Construction Management and Economics, 19(2), 135–44.

Porter, M. E. (1980). “Competitive strategy: Techniques for analyzing industries and competitors”, Free Press, New York/Collier Macmillan, London.

Porter, M. E. (1998). “Competitive advantage: Creating and sustaining superior performance”, Free Press, New York/Collier Macmillan, London.

Porter, M. E. (2008). “On Competition”, A Harvard Business Review Book.

Powell J.M, “The New Competitive in Design & Construction”, John Wiley & Sons, Ltd, 2008.

Prahalad, C.K. and Hamel, G. (1990) “The core competence of the corporation”. Harvard Business Review, 68(3), 79–91.

Prahalad, C.K. and Hamel, G. (2006) “The core competence of the corporation”. Harvard Business Review, 68(3), 79–91.

Randy R. Rapp, P.E (2001) “Business Strategy: Ideas for Construction Master’s Degrees”. Leadership and Management in Engineering, Vol. 1, No. 2, April 2001, p. 3 7.

Revisiting the Fundamentals of Competitiveness: A Proposal- IMD WORLD COMPETITIVENESS YEARBOOK 2015.

Roberts, R. and Goodwin, P. (2002). "Weight approximations in multi-attribute decision models." Journal of Multi-Criteria Decision Analysis, 11(6), 291-303.

Roder, A. and Tibken, B. (2006). "A fuzzy optimization model for QFD planning process using analytic network approach." Eur.J.Oper.Res. 169(3), 1010-1029.

Ross, T. J. (2010). Fuzzy logic with engineering applications (2nd edition). John Wiley & Sons, Ltd

Roy, B. (1990). "Decision-aid and decision-making." Eur.J.Oper.Res. 45(2-3), 324- 331.

Roy, B. (2013). Multicriteria methodology for decision aiding. Springer Science & Business Media.

Roy, B. and Vincke, P. (1987). "Pseudo-orders: definition, properties and numerical representation." Mathematical Social Sciences, 14(3), 263-274.

Saaty, T. L. (2001). "Analytic network process." Encyclopedia of Operations Research and Management Science, Springer, 28-35.

Saaty, T. L. (2006). "The analytic network process." Decision making with the analytic network process, Springer, 1-26.

Saaty. (2008). "The Analytic Hierarchy and Analytic Network Measurement Processes: Applications to decisions under Risk." J. European Journal of Pure and Applied Mathematics, 1(1), 122-196.

Schmuck, R. (2009). (2009).Competitiveness Index: A method of measuring company excellence. University of Pecs, Hungary.

Schrettle, Stefan, et al.(2014).Turning sustainability into action: Explaining firms' sustainability efforts and their impact on firm performance. International Journal of Production Economics 147: 73-84.

Sha K. X. (2008). Competitiveness assessment system for China’s construction industry. Journal of Building research and information, 36(1), 97-109.

Shurchuluu (2002).National productivity and competitive strategies for the new millennium. Integrated Manufacturing Systems, 13(8), 408-414

Tan, Yongtao (2009). Contractor's competitiveness and competitive strategy in Hong Kong. Ph.D. thesis, Hong Kong Polytechnic Univ., Hong Kong.

Truong-Van L.(2008).Performance measurement of construction firms in Developing countries. Construction Management and Economics.

Wang, Y., Elhag, T., & Hua, Z. (2006). A modified fuzzy logarithmic least squares method for fuzzy analytic hierarchy process. J. Fuzzy Sets and Systems, 157 (23), 3055-3071.

Warszawski, A. (1996). Strategic planning in construction companies. J. Constr. Eng. Manage. 122(2), 133–140.

Wei, M., Russell, D. W., Mallinckrodt, B., & Vogel, D. L. (2007). The Experiences in Close Relationship Scale (ECR)short Form: Reliability, validity, and factor structure. Journal of Personality Assessment, 88, 187–204.

Wethyavivorn P. et al (2009).Strategic Assets Driving Organizational Capabilities of Thai Construction Firms.Journal of Construction Engineering and Management, 135(11), 1222-1231.

Wibson, R.(2009).Innovation to the core: A Blueprint for Transforming the Way Your Company Innovates. Harvard Business Press.

Wong, C. H., Holt, G. D., and Cooper, P. A. (2000). Lowest price or value?

World Economic Forum (WEF). (2009). Global Competitiveness Report 2008-2009, Geneva.

Wu, C.R. and Chang, C.W. (2008). A fuzzy ANP-based approach to evaluate medical organizational performance. J. Information and Management Sciences, 19(1), 53-74.

Xu. (2000). Fuzzy least-squares priority method in the analytic hierarchy process. J. Fuzzy Sets and Systems, 112(3), 395-404.

Yang, H., Chan, A., and Yeung, J. (2013). Niche Width, Competitive Positioning, and Performance of International Construction Contractors (1992–2009). Journal of Management in Engineering,

Yisa, S. B., Ndekugri, I., and Ambrose, B. (1996). A review of changes in the UK construction industry: Their implications for the marketing of construction services. E ur.J. Market., 30(3), 47–64.

Yongtao, Tan (2009). Contractor's competitiveness and competitive strategy in Hong Kong. Ph.D. thesis, Hong Kong Polytechnic Univ., Hong Kong.

Zhou, X. (2012). Fuzzy Analytical Network Process Implementation with Matlab." MATLAB – A Fundamental Tool for Scientific Computing and Engineering Applications – 3:133-160.

Zopounidis, C. and Doumpos, M. (2002). Multicriteria classification and sorting methods: A literature review. Eur.J.Oper.Res. 138(2), 229-246.

APPENDIX (A)

COMPETITIVENESS INDEX FOR CONSTRUCTION COMPANIES

QUESTIONNAIRE

UNIVERSITÉ Concordia UNIVERSITY

COMPETITIVENESS INDEX FOR CONSTRUCTION COMPANIES

Dear Sir/Madam

We would like to present our appreciation and thanks to you for taking part of your time to complete this questionnaire. This questionnaire aims to identify the importance of the factors affecting the Construction companies' competitiveness. This questionnaire is a part of the requirements for an academic research which is done under the supervision of Concordia Universities to build a competitiveness index model for construction companies. The information in the questionnaire will be used for academic research with complete commitment for absolute confidentiality to your information.

SECTION 1: BACKGROUND OF THE RESPONDENT

Kindly provide your personal details:

Name

Work place*

Address

E-mail *

Phone

Kindly provide your organization details:

Work categorization *

- Owner
- Consultant
- Contractor

Work categorization *

- private sector
- public sector

Construction type *

- Infrastructure
- Industrial
- Real state

Average annual work Load *

- less than one million USD
- 1-5 million USD
- 5-20 million USD
- more than 20 million USD

Company Size *

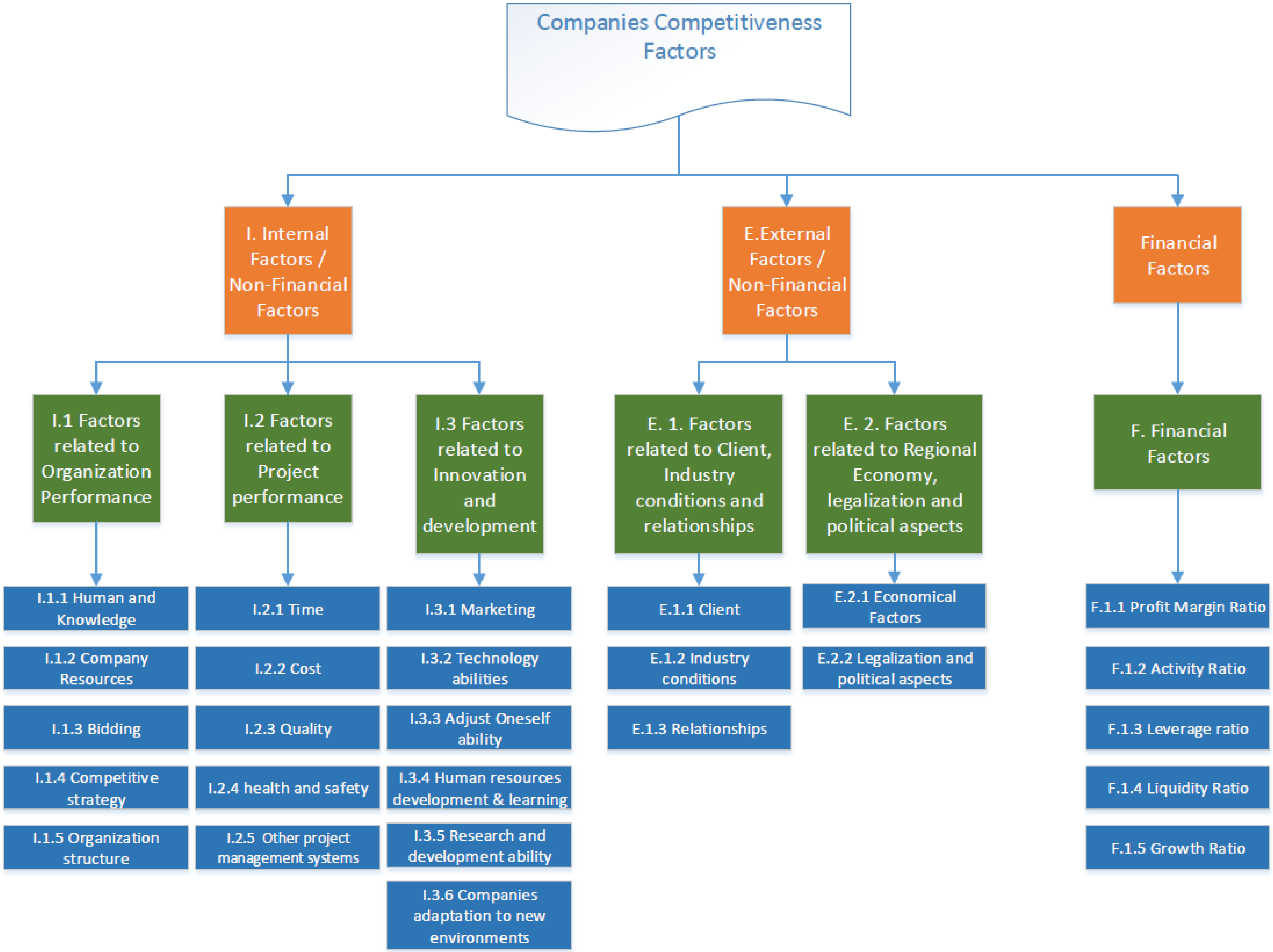
- Small (less than one million USD)
- Medium (1-20 million USD)
- Large (20-100 million USD or more)

Previous experience in construction industry *

- 1-5 Years
- 5-10 Years
- 10-15 Years
- More than 15 Years

SECTION 2: FACTORS AFFECTING COMPANIES' COMPETITIVENESS BREAK DOWN

There are several factors that could affect the competiveness of companies. These factors are divided into Non-Financial Internal Factors, Non-Financial External Factors and Financial Factors, as shown in Figure 1. This classification is based on our opinion and you would be kindly requested to provide your feedback in the different relevant sections when deemed necessary.


Companies Competitiveness Factors
I. Internal Factors / Non-Financial Factors
E.External Factors / Non-Financial Factors
Financial Factors
I.1 Factors related to Organization Performance
I.2 Factors related to Project performance
I.3 Factors related to Innovation and development
E. 1. Factors related to Client, Industry conditions and relationships
E. 2. Factors related to Regional Economy, legalization and political aspects
F. Financial Factors
I.1.1 Human and Knowledge
I.1.2 Company Resources
I.1.3 Bidding
I.1.4 Competitive strategy
I.1.5 Organization structure
I.2.1 Time
I.2.2 Cost
I.2.3 Quality
I.2.4 health and safety
I.2.5 Other project management systems
I.3.1 Marketing
I.3.2 Technology abilities
I.3.3 Adjust Oneself ability
I.3.4 Human resources development & learning
I.3.5 Research and development ability
I.3.6 Companies adaptation to new environments
E.1.1 Client
E.1.2 Industry conditions
E.1.3 Relationships
E.2.1 Economical Factors
E.2.2 Legalization and political aspects
F.1.1 Profit Margin Ratio
F.1.2 Activity Ratio
F.1.3 Leverage ratio
F.1.4 Liquidity Ratio
F.1.5 Growth Ratio

Based on review of the literature, the main factors that were found to have an effect on competitiveness of construction companies are shown in Table 1, 2 & 3. We would like to have your input for the importance of the main branching (Internal/Non-Financial, External/Non-Financial and Financial Branches) (Table 1). Then you are kindly requested to provide your opinion for the importance of the main factors in each branch (Table 2). Lastly, you are kindly requested to provide your opinion for the sub factors in (table 3). For all tables you will be requested to fill in column (B) with the importance from Very Weak to Very Strong based on each factor on the competitiveness of the company. Very low represents the least effect and/or importance while very high represents the most effect and/or importance. Also, for table 3 you are kindly requested to fill up Column (C) with the Maximum and Minimum Values for the factors' threshold. The Values should be based on the nature of the factors (i.e. monetary values, %, numbers, Etc.)

Table 1

Factors (A)	Description	Effect / importance on companies' Competitiveness (B)					Comments
		Very Weak	Weak	Medium	Strong	Very Strong	
I. Internal / Non-Financial	**Description:** Internal factors are those which management can take action on them in order to achieve its goals. Examples include leadership, training, and innovation						
E. External / Non-Financial	**Description:** External factors, originate outside the company and management has little, if any, influence over them. Examples include regulations, number of competitors, interest rates, and public investment. These external factors form the environment in which companies have to compete, resulting in a different competitive atmosphere for each individual industry or country						
F. Financial	**Description:** A group of factors/Indices that shows how the company is performing financially. Also, it shows the rate at which companies have grown profits and is used to measure a company's ability to pay its short-term debt. Such as; Profit Margin Ratio, Activity Ratio, Leverage ratio Liquidity Ratio and growth ratio						

Table 2

Factors (A)		Description	Effect / importance on companies' Competitiveness (B)					Comments
			Very Weak	Weak	Medium	Strong	Very Strong	
I. Internal / Non-Financial	I.1. Organization Performance	**Description:** construction organizations have to take into consideration in labor skills and experts' as to establish a feasible competitive strategy. Advancements in construction knowledge and technology require additional education, cooperation, and strategy management at a company level.						
	I.2. Project Performance	**Description:** Time, cost, and quality are so far recorded as the three main factors for project management. Also, other project management systems such as (Risk Management, Site Management, Contract Management, Claims Management, Logistic and supply chain Management, Environmental Management) In which they are also vital, when studying competitiveness.						
	I.3. Innovation and development	**Description:** When addressing a competitive strategy, a construction company should include a strategy for development, for consciousness, and for clear missions and goals To develop and innovate, a company should invest in building up their human resources, attract labor, and carefully recruit staff. Human resource development & learning One of the most important innovations and developments also, the ability of the company to coupe to the advancement of IT technology, Flexibility and adjustment ability are vital factors for competitiveness.						
E. External Factors / Non-Financial	E. 1. Client, Industry conditions and relationships	**Description:** To sustain a competitive ability, a construction company should satisfy clients' demands concerning products and services. Also the Industry condition should be addressed when analyzing a company's competitiveness. City laws and regulations, market conditions, supplier demands all these have an impact on the competitiveness environment. Relationships with subcontractors, suppliers, designers, consultants, government departments, and the public sector should be addressed as well.						
	E. 2. Regional Economy, legalization and political aspects	**Description:** Economical conditions are essential factor, Attractiveness of contracting with foreign currency, Recession in the domestic construction market are vial for competitiveness. Also, Company competitiveness is sensitive when it is to be faced by aspects such as; Corruption and lack of transparency, Political instability, Inconsistencies in government policies and laws, Health and safety issues, Procurement act & legislation, Lack of government guarantees and Demand for construction						
F. Financial Factors	F.1 Financial factors	**Description:** A group of factors/Indices that shows how the company is performing financially. Also, it shows the rate at which companies have grown profits and is used to measure a company's ability to pay its short-term debt. Such as; Profit Margin Ratio, Activity Ratio, Leverage ratio Liquidity Ratio and growth ratio						

Table 3

		Factors (A)	Description / Measuring unit	Effect / importance on companies' Competitiveness (B)					Threshold (C)		Comments
				Very Weak	Weak	Medium	Strong	Very Strong	Min	Max	
I. Internal Factors / Non-Financial	I.1. Organization Performance	I.1.1 Human and Knowledge	**Description:** Most competitive theories consider personnel and their knowledge to be among important factors of a company's competitive ability, employee productivity is a vital indicator of competitiveness. **Measuring Unit:** Employee productivity ($ per year)								
		I.1.2 Company resources	**Description:** Managers should take into consideration company's resources, This factor help the company sustain competitiveness. The Effective use of organization's resources is vital. **Measuring Unit:** Require threshold based on the efficiency of utilizing your companies' resources (weak, moderate, strong)								
		I.1.3 Bidding	**Description:** Construction companies use competitive bidding to achieve the best possible value and several decision support tools for construction bidding. Competitive company is a company who have been developed Experience for bidding & has the availability of resources and professionals for bidding **Measuring Unit:** Success rate (%) of bidding over past 3 years								
		I.1.4 Competitive strategy	**Description:** Every firm competing in an industry has a competitive strategy. A company should have a clear vision, mission and goals, and strategic awareness when developing a competitive strategy. Vision, missions and goals are the starting points for all company endeavors. Once a company has a strategy to follow, it can confront the challenge of implementation. **Measuring Unit:** Require threshold based on your companies 'efficiency in strategy implementation (weak, moderate, strong)								
		I.1.5 Organization structure	**Description:** In a globalization market, the upper management should consider the company's international standing. Communication protocols between departments, projects, staffs, customers and stakeholders. All will affect company competitive ability and business. The role of team leaders' throughout the departments is important for company competitiveness. **Measuring Unit:** Require threshold based on Leader Efficiency								
	I.2. Project Performance	I.2.1 Time	**Description:** Numerous numbers of published papers stating the importance of this factor concerning project performance. **Measuring Unit:** Schedule performance index (SPI)								
		I.2.2 Cost	**Description:** Numerous numbers of published papers stating the importance of this factor concerning project performance. **Measuring Unit:** Cost performance Index (CPI)								
		I.2.3 Quality	**Description:** Numerous numbers of published papers stating the importance of this factor concerning project performance. Effectiveness of quality management is vital **Measuring Unit:** Total quality accidents per year ($)								
		I.2.4 health and safety	**Description:** The construction industry has the second highest rate of injury and illness of all industries, and with the competitive initiative of all companies nowadays in achieving a zero accidents. thus health and safety is considered Vital **Measuring Unit:** Reportable accidents per 100,000 hours worked								
		I.2.5 Other project management systems	**Description:** Other project management systems such as (Risk Management, Site Management, Contract Management, Claims Management, Logistic and supply chain Management, Environmental Management) In which they are also vital, when studying competitiveness. **Measuring Unit:** Require threshold based on your companies' ability in performing efficiently (weak, moderate, strong)								
	I.3. Innovation and development	I.3.1 Marketing	**Description:** Important factor for addressing a company's competitive ability. Since the market is exponentially advancing, the competition is higher and Client's tasks are increased the experience of the company in the market is Vital. **Measuring Unit:** Number of years of experience in the market								
		I.3.2 Technology abilities	**Description:** Technology innovation ability & Technical application One of the most important innovations and developments is the advancement of IT technology. It connects people, customers to project sites, etc. The application of IT and technologies to business has become a fundamental **Measuring Unit:** Ratio of technology contribution per total revenue (%)								
		I.3.3 Adjust Oneself ability	**Description:** Flexibility and adjustment ability are vital factors for competitiveness in the present time. With the increase of globalization and competition, a construction company should adjust its management as to be compatible with its environment. **Measuring Unit:** Entry new or region or new types of construction projects (%)								
		I.3.4 Human resources development & learning	**Description:** A company should invest in building up their human resources, attract labor, and carefully recruit staff. The stronger the team members are the more compete the company is. **Measuring Unit:** Money invest per one employee (for enhancements, training and education) per year								
		I.3.5 Research and development ability	**Description:** Research and development will help the organization improve its core Competencies competitive ability, and create new tools to address prospective challenges. **Measuring Unit:** Ratio of R&D contribute per total revenue $/$ (%)								
		I.3.6 Companies adaptation to new environments	**Description:** The current environment demands a new brand of teams. One that emphasizes outreach to stakeholders and adapt easily to flatter organizational structures. Changing information and increasing complexity **Measuring Unit:** Require threshold based on Companies' adaptation ability (weak, moderate, strong)								

Factors (A)			Description / Measuring Unit	Effect / importance on companies' Competitiveness (B)					Threshold		Comments
				Very Weak	Weak	Medium	Strong	Very Strong	Min	Max	
E. External Factors / Non-Financial	E. 1. Client, Industry conditions and relationships	E.1.1 Client	**Description:** To sustain a competitive ability, a construction company should satisfy clients' demands concerning products and services. It can be measured Clients' satisfaction with (the value for money on delivered products and services) **Measuring Unit:** Require threshold based on the company's ability to address the client's demands (weak, moderate, strong)								
		E.1.2 Industry conditions	**Description:** Industry condition should be addressed when analyzing a company's competitiveness. City laws and regulations, market conditions, supplier demands **Measuring Unit:** Require threshold based on companies' ability to abiding to local regulations and laws (weak, moderate, strong)								
		E.1.3 Relationships	**Description:** Relationships with subcontractors, suppliers, designers, consultants, government departments, and the public sector should be addressed **Measuring Unit:** Require threshold based on how well are relationships with different stakeholders (weak, moderate, strong)								
	E. 2. Regional Economy, legalization and political aspects	E.2.1 Economical Factors	**Description:** Economical conditions are essential factor, Attractiveness of contracting with foreign currency, Recession in the domestic construction market are vial for competitiveness **Measuring Unit:** Require threshold based on (GDP for the country the company is to be competing in)								
		E.2.2 Legalization and political aspects	**Description:** Company competitiveness is sensitive when it is to be faced by these aspects such as; Corruption and lack of transparency, Political instability, Inconsistencies in government policies and laws, Health and safety issues, Procurement act & legislation, Lack of government guarantees and Demand for construction **Measuring Unit:** Require score based on your opinion.								

Factors (A)			Description / Measuring Unit	Effect / importance on companies' Competitiveness (B)					Threshold		Comments
				Very Weak	Weak	Medium	Strong	Very Strong	Min	Max	
F. Financial Factors	F.1 Financial factors	F.1.1 Profit Margin Ratio	**Description:** The profit margin ratio, also called the return on sales ratio or gross profit ratio, is a profitability ratio that measures the amount of net income earned with each dollar of sales generated by comparing the net income and net sales of a company. In other words, the profit margin ratio shows what percentage of sales are left over after all expenses are paid by the business. **Measuring Unit:** Please provide the Max and Min. thresholds for the profit margin ratio: Net income /Net sales (%)								
		F.1.2 Activity Ratio	**Description:** Activity ratios, sometimes referred to as operating ratios or management ratios, measure the efficiency with which a business uses its assets **Measuring Unit:** Please provide the Max and Min. thresholds for the Activity Ratio: sales / total assets								
		F.1.3 Leverage ratio	**Description:** The debt to equity ratio that gives you an idea about the debt one company is in and the equity it has at its disposal. Leverage ratios also determine the company's cost mix and its effects on the operating income. Companies with high fixed cost earn more income because after the breakeven point, with the increase in output the income increases as the cost has already been incurred **Measuring Unit:** Please provide the Max and Min. thresholds for : Leverage ratio Total debt / Total assets								
		F.1.4 Liquidity Ratio	**Description:** The term liquidity is defined as the ability of a company to meet its financial obligations as they come due. The liquidity ratio, then, is a computation that is used to measure a company's ability to pay its short-term debt **Measuring Unit:** Current Assets less inventories / Current liabilities								
		F.1.5 Growth Ratio	**Description:** Net income growth is the percentage gain (or loss) in net income from a year to another. It is a good indicator of the rate at which companies have grown profits. **Measuring Unit:** Income growth= Current year's profit / Prior year's profit								

APPENDIX (B)

MATLAB Codes

FANP Code;

1. CodeIEF

```
Aeq=[1 1 1 0];
beq=[1];
VLB = [0; 0; 0; -inf];
VUB = [ ];
x0 = [0.4; 0.4; 0.2; 1];
OPT = optimset('LargeScale', 'off');
[x, fval] = fmincon('IEF', x0, [ ], [ ],Aeq, beq, VLB, VUB, 'CodeIEF', OPT)
function f =IEF(x);
f = -x(4);
function [c, ceq] = CodeIEF (x);
c = [
(1-1)*x(4)*x(2)-x(1)+(1)*x(2);
(1.5-1)*x(4)*x(2)+x(1)-(1.5)*x(2);
(7/9-6.5/8.5)*x(4)*x(3)-x(1)+(6.5/8.5)*x(3);
(7.5/9-7/9)*x(4)*x(3)+x(1)-(7.5/9)*x(3);
(7/9-6.5/8.5)*x(4)*x(3)-x(2)+(6.5/8.5)*x(3);
(7.5/9-7/9)*x(4)*x(3)+x(2)-(7.5/9)*x(3);
];
ceq = [ ];

x =
0.3043
0.3043
0.3913
1
fval =
```

2. CodeI1

```
Aeq=[1 1 1 0];
beq=[1];
VLB = [0; 0; 0; -inf];
VUB = [ ];
x0 = [0.4; 0.4; 0.2; 1];
OPT = optimset('LargeScale', 'off');
[x, fval] = fmincon('I1', x0, [ ], [ ],Aeq, beq, VLB, VUB, 'CodeI1', OPT)
function f =I1(x);
f = -x(4);
function [c, ceq] = CodeI1 (x);
c = [
(5/7-4.5/6.5)*x(4)*x(2)-x(1)+(4.5/6.5)*x(2);
(5.5/7.5-5/7)*x(4)*x(2)+x(1)-(5.5/7.5)*x(2);
(5/3-4.5/2.5)*x(4)*x(3)-x(1)+(4.5/2.5)*x(3);
(5.5/3.5-5/3)*x(4)*x(3)+x(1)-(5.5/3.5)*x(3);
(7/3-6.5/2.5)*x(4)*x(3)-x(2)+(6.5/2.5)*x(3);
(7.5/3.5-7/3)*x(4)*x(3)+x(2)-(7.5/3.5)*x(3);
];
ceq = [ ];
x =
```

0.3333
0.4667
0.2
1
fval =
-1

4. CodeI31

```
Aeq=[1 1 1 1 1 0];
beq=[1];
VLB = [0; 0; 0; 0; 0; -inf];
VUB = [ ];
x0 = [0.2; 0.2; 0.2; 0.2; 0.2; 1];
OPT = optimset('LargeScale', 'off');
[x, fval] = fmincon('I31', x0, [ ], [ ],Aeq, beq, VLB, VUB, 'CodeI31', OPT)

function f =I31(x);
f = -x(6);
function [c, ceq] = CodeI31 (x);
c = [
(1-1)*x(6)*x(2)-x(1)+(1)*x(2);
(1.5-1)*x(6)*x(2)+x(1)-(1.5)*x(2);
(1-1)*x(6)*x(3)-x(1)+(1)*x(3);
(1.5-1)*x(6)*x(3)+x(1)-(1.5)*x(3);
(9/3-8.5/2.5)*x(6)*x(4)-x(1)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(6)*x(4)+x(1)-(9/3.5)*x(4);
(1-1)*x(6)*x(5)-x(1)+(1)*x(5);
(1.5-1)*x(6)*x(5)+x(1)-(1.5)*x(5);
(1-1)*x(6)*x(3)-x(2)+(1)*x(3);
(1.5-1)*x(6)*x(3)+x(2)-(1.5)*x(3);
(9/3-8.5/2.5)*x(6)*x(4)-x(2)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(6)*x(4)+x(2)-(9/3.5)*x(4);
(1-1)*x(6)*x(5)-x(2)+(1)*x(5);
(1.5-1)*x(6)*x(5)+x(2)-(1.5)*x(5);
(9/3-8.5/2.5)*x(6)*x(4)-x(3)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(6)*x(4)+x(3)-(9/3.5)*x(4);
(1-1)*x(6)*x(5)-x(3)+(1)*x(5);
(1.5-1)*x(6)*x(5)+x(3)-(1.5)*x(5);
(3/9-2.5/8.5)*x(6)*x(5)-x(4)+(2.5/8.5)*x(5);
(3.5/9-3/9)*x(6)*x(5)+x(4)-(3.5/9)*x(5);
];
ceq = [ ];
```

x =
0.2308
0.2308
0.2308
0.0769
0.2308
1
fval =
-1

5.CodeI32

```
Aeq=[1 1 1 1 1 0];
beq=[1];
VLB = [0; 0; 0; 0; 0; -inf];
VUB = [ ];
x0 = [0.2; 0.2; 0.2; 0.2; 0.2; 1];
OPT = optimset('LargeScale', 'off');
[x, fval] = fmincon('I32', x0, [ ], [ ],Aeq, beq, VLB, VUB, 'CodeI32', OPT)
function f =I32(x);
f = -x(6);
function [c, ceq] = CodeI32 (x);
c = [
(1-1)*x(6)*x(2)-x(1)+(1)*x(2);
(1.5-1)*x(6)*x(2)+x(1)-(1.5)*x(2);
(1-1)*x(6)*x(3)-x(1)+(1)*x(3);
(1.5-1)*x(6)*x(3)+x(1)-(1.5)*x(3);
(9/3-8.5/2.5)*x(6)*x(4)-x(1)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(6)*x(4)+x(1)-(9/3.5)*x(4);
(1-1)*x(6)*x(5)-x(1)+(1)*x(5);
(1.5-1)*x(6)*x(5)+x(1)-(1.5)*x(5);
(1-1)*x(6)*x(3)-x(2)+(1)*x(3);
(1.5-1)*x(6)*x(3)+x(2)-(1.5)*x(3);
(9/3-8.5/2.5)*x(6)*x(4)-x(2)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(6)*x(4)+x(2)-(9/3.5)*x(4);
(1-1)*x(6)*x(5)-x(2)+(1)*x(5);
(1.5-1)*x(6)*x(5)+x(2)-(1.5)*x(5);
(9/3-8.5/2.5)*x(6)*x(4)-x(3)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(6)*x(4)+x(3)-(9/3.5)*x(4);
(1-1)*x(6)*x(5)-x(3)+(1)*x(5);
(1.5-1)*x(6)*x(5)+x(3)-(1.5)*x(5);
(3/9-2.5/8.5)*x(6)*x(5)-x(4)+(2.5/8.5)*x(5);
(3.5/9-3/9)*x(6)*x(5)+x(4)-(3.5/9)*x(5);
];
ceq = [ ];
x =
0.2308
0.2308
0.2308
0.0769
0.2308
1
fval =
-1
```

6. CodeI33

```
Aeq=[1 1 1 1 1 1 0];
beq=[1];
VLB = [0; 0; 0; 0; 0; 0; -inf];
VUB = [ ];
x0 = [0.175; 0.175; 0.1; 0.175; 0.175; 0.2; 1];
OPT = optimset('LargeScale', 'off');
```

```
[x, fval] = fmincon('I33', x0, [ ], [ ],Aeq, beq, VLB, VUB, 'CodeI33', OPT)
function f =I33(x);
f = -x(7);
function [c, ceq] = CodeI33 (x);
c = [
(1-1)*x(7)*x(2)-x(1)+(1)*x(2);
(1.5-1)*x(7)*x(2)+x(1)-(1.5)*x(2);
(1-1)*x(7)*x(3)-x(1)+(1)*x(3);
(1.5-1)*x(7)*x(3)+x(1)-(1.5)*x(3);
(9/3-8.5/2.5)*x(7)*x(4)-x(1)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(7)*x(4)+x(1)-(9/3.5)*x(4);
(1-1)*x(7)*x(5)-x(1)+(1)*x(5);
(1.5-1)*x(7)*x(5)+x(1)-(1.5)*x(5);
(1-1)*x(7)*x(6)-x(1)+(1)*x(6);
(1.5-1)*x(7)*x(6)+x(1)-(1.5)*x(6);
(1-1)*x(7)*x(3)-x(2)+(1)*x(3);
(1.5-1)*x(7)*x(3)+x(2)-(1.5)*x(3);
(9/3-8.5/2.5)*x(7)*x(4)-x(2)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(7)*x(4)+x(2)-(9/3.5)*x(4);
(1-1)*x(7)*x(5)-x(2)+(1)*x(5);
(1.5-1)*x(7)*x(5)+x(2)-(1.5)*x(5);
(1-1)*x(7)*x(6)-x(2)+(1)*x(6);
(1.5-1)*x(7)*x(6)+x(2)-(1.5)*x(6);
(9/3-8.5/2.5)*x(7)*x(4)-x(3)+(8.5/2.5)*x(4);
(9/3.5-9/3)*x(7)*x(4)+x(3)-(9/3.5)*x(4);
(1-1)*x(7)*x(5)-x(3)+(1)*x(5);
(1.5-1)*x(7)*x(5)+x(3)-(1.5)*x(5);
(1-1)*x(7)*x(6)-x(3)+(1)*x(6);
(1.5-1)*x(7)*x(6)+x(3)-(1.5)*x(6);
(3/9-2.5/8.5)*x(7)*x(5)-x(4)+(2.5/8.5)*x(5);
(3.5/9-3/9)*x(7)*x(5)+x(4)-(3.5/9)*x(5);
(3/9-2.5/8.5)*x(7)*x(6)-x(4)+(2.5/8.5)*x(6);
(3.5/9-3/9)*x(7)*x(6)+x(4)-(3.5/9)*x(6);
(3/9-2.5/8.5)*x(7)*x(6)-x(5)+(2.5/8.5)*x(6);
(3.5/9-3/9)*x(7)*x(6)+x(5)-(3.5/9)*x(6);
];
ceq = [ ];
x =
0.1992
0.1992
0.1992
0.0661
0.111
0.2253
-0.3391
fval =
0.3391
```

7. CodeE2E1

```
Aeq=[1 1 1 0];
beq=[1];
```

```
VLB = [0; 0; 0; -inf];
VUB = [ ];
x0 = [0.4; 0.4; 0.2; 1];
OPT = optimset('LargeScale', 'off');
[x, fval] = fmincon('E2E1', x0, [ ], [ ],Aeq, beq, VLB, VUB, 'CodeE2E1', OPT)
function f =E2E1(x);
f = -x(4);
function [c, ceq] = CodeE2E1 (x);
c = [
(1-1)*x(4)*x(2)-x(1)+(1)*x(2);
(1.5-1)*x(4)*x(2)+x(1)-(1.5)*x(2);
(9/7-8.5/6.5)*x(4)*x(3)-x(1)+(8.5/6.5)*x(3);
(9/7.5-9/7)*x(4)*x(3)+x(1)-(9/7.5)*x(3);
(9/7-8.5/6.5)*x(4)*x(3)-x(2)+(8.5/6.5)*x(3);
(9/7.5-9/7)*x(4)*x(3)+x(2)-(9/7.5)*x(3);
];
ceq = [ ];
x =
0.36
0.36
0.28
1
fval =
-1
```

9. CodeF2F1

```
Aeq=[1 1 1 1 1 0];
beq=[1];
VLB = [0; 0; 0; 0; 0; -inf];
VUB = [ ];
x0 = [0.2; 0.2; 0.2; 0.2; 0.2; 1];
OPT = optimset('LargeScale', 'off');
[x, fval] = fmincon('F2F1', x0, [ ], [ ],Aeq, beq, VLB, VUB, 'CodeF2F1', OPT)


function f =F2F1(x);
f = -x(6);
function [c, ceq] = CodeF2F1 (x);
c = [
(5/9-4.5/8.5)*x(6)*x(2)-x(1)+(4.5/8.5)*x(2);
(5.5/9.5-5/9)*x(6)*x(2)+x(1)-(5.5/9.5)*x(2);
(5/1-4.5/1)*x(6)*x(3)-x(1)+(4.5/1)*x(3);
(5.5/1.5-5/1)*x(6)*x(3)+x(1)-(5.5/1.5)*x(3);
(5/9-4.5/8.5)*x(6)*x(4)-x(1)+(4.5/8.5)*x(4);
(5.5/9-5/9)*x(6)*x(4)+x(1)-(5.5/9)*x(4);
(5/3-4.5/2.5)*x(6)*x(5)-x(1)+(4.5/2.5)*x(5);
(5.5/3.5-5/3)*x(6)*x(5)+x(1)-(5.5/3.5)*x(5);
(9/1-8.5/1)*x(6)*x(3)-x(2)+(8.5/1)*x(3);
(9/1.5-9/1)*x(6)*x(3)+x(2)-(9/1.5)*x(3);
(1-1)*x(6)*x(4)-x(2)+(1)*x(4);
(1.5-1)*x(6)*x(4)+x(2)-(1.5)*x(4);
```

```
(9/3-8.5/2.5)*x(6)*x(5)-x(2)+(8.5/2.5)*x(5);
(9/3.5-9/3)*x(6)*x(5)+x(2)-(9/3.5)*x(5);
(1/9-1/8.5)*x(6)*x(4)-x(3)+(1/8.5)*x(4);
(1.5/9-1/9)*x(6)*x(4)+x(3)-(1.5/9)*x(4);
(1/3-1/2.5)*x(6)*x(5)-x(3)+(1/2.5)*x(5);
(1.5/3.5-1/3)*x(6)*x(5)+x(3)-(1.5/3.5)*x(5);
(9/3-8.5/2.5)*x(6)*x(5)-x(4)+(8.5/2.5)*x(5);
(9/3.5-9/3)*x(6)*x(5)+x(4)-(9/3.5)*x(5);
];
ceq = [ ];
x =
0.1852
0.3333
0.037
0.3333
0.1111
1
fval =
-1
```

PROMETHEE Code;

```
close all;
f = figure('Name', 'Competitive Index For Construction Companies','Position',[500 200 400 300]);
panel = uipanel('Parent',f,'Title','Competitive Index','Position',[.1 .1 .8 .8]);
altText = uicontrol(panel,'Style','edit','String','Evaluation_Table.xls','Units','normalized','Position',[.05 .82 .65 .1]);
weightText = uicontrol(panel,'Style','edit','String','Weights.xls','Units','normalized','Position',[.05 .56 .65 .1]);
consText = uicontrol(panel,'Style','edit','String','Constraints.xls','Units','normalized','Position',[.05 .3 .65 .1]);
altBtn = uicontrol(panel,'Callback',{@FindFile,altText},'String','Select','Units','normalized','Position',[.75 .78 .2 .2]);
weightBtn = uicontrol(panel,'Callback',{@FindFile,weightText},'String','Select','Units','normalized','Position',[.75 .52 .2 .2]);
consBtn = uicontrol(panel,'Callback',{@FindFile,consText},'String','Select','Units','normalized','Position',[.75 .26 .2 .2]);
processBtn = uicontrol(panel,'Callback','PrometheeV(get(altText,''String''),get(weightText,''String''),get(consText,''String''))','String','Calculate','Units','normalized','Position',[.3 .02 .4 .2]);


function [best_table] = PrometheeV(alternative_file, weights_file, constr_file)
   alternative_values = xlsread(alternative_file);
   C = importdata('alternatives.csv','\n');
   f = figure('Name','Alternatives','Position',[30 200 750 500]);
   dat = 1:9;
   t = uitable('Parent',f,'Data',dat,'ColumnName','Nr','RowName',C,'Position',[20 20 720 480]);
   set(t,'ColumnWidth',{30});
   ranking = prometheeII(alternative_values, weights_file);
   constrains = xlsread(constr_file);
   con_nbr = size(constrains);
   crit_nbr = size(alternative_values);
   A= zeros(crit_nbr(1),con_nbr(2));
   if con_nbr(2) > 0
      for i=1:con_nbr(2)
         A(:,i) =  alternative_values(:,constrains(1,i));
      end
      b = constrains(2,:)';
      [x,fval] = bintprog(-ranking,A',b);
```

```
        best_set = zeros(size(x),2);
        best_table = zeros(sum(x),2);
        ii = 1;
        for j=1:size(x)
            best_set(j,1) = j;
            if x(j)==1
                best_set(j,2) = ranking(j);
                best_table(ii,1) = j;
                best_table(ii,2) = ranking(j);
                ii = ii + 1;
            else
                best_set(j,2) = 0;
            end
        end
        figure('Name','Results','Position',[700,100,500,300]);
        hold on;
        alt_nbr = size(ranking);
        label = java_array('java.lang.String', alt_nbr(2));
        for i=1:alt_nbr(2)
            label(i) = java.lang.String( num2str(i));
        end
        bar(ranking);
        set(gca,'XTickLabel',cell(label),'XTick',1:numel(label),'XLim',[alt_nbr(1)-1
alt_nbr(2)+1]);
        set(gca,'FontSize',7);
        bar(best_set(:,1), best_set(:,2),'green');
        hold off;
        s = size(best_table);
        f = figure('Name','Results','Position',[450 100 139 25*s(1)]);
        t2          =           uitable('Parent',f,'Data',best_table(:,2),'ColumnName','Net
Flow','RowName',best_table(:,1),'Units','normalized','Position',[.05 .05 .9 .9]);
        set(t2,'ColumnWidth',{90});
    else
        best_table = ranking(1);
    end

    function [prefer] = prefFunction(a,b,p,q,dir)
    d = dir*(a-b);
    if d >= p
        prefer =1;
    else if d <= q
            prefer = 0;
        else
            prefer = (d-q)/(p-q);
        end
    end
end
```