Optimization of Contractor Selection Procedures for Road Construction Projects in Yemen: AHP-TOPSIS Based Model

Suhaib Khaled F. Al-Akwaa

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Master of Science
in
Civil Engineering

Eastern Mediterranean University
July 2022
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Ali Hakan Ulusoy
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science in Civil Engineering.

Prof. Dr. Umut Türker
Chair, Department of Civil Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Civil Engineering.

Assoc. Prof. Dr. Tolga Çelik
Supervisor

Examining Committee

1. Prof. Dr. Mürüde Çelikağ

2. Assoc. Prof. Dr. Tolga Çelik

3. Asst. Prof. Dr. Osman İlter

ABSTRACT

The construction sector is among the essential industries of any country's economy. Clients or organizations must make an important decision when selecting a contractor since it is vital to the success of any project. The construction industry is developing, and projects are becoming more complex; as a result, the traditional practice of tender award is not convenient anymore, and enhancement is needed due to the problems arising from conducting the lowest-price award practice. The following research focuses on developing a decision-making framework to assist in selecting a competent contractor and establishing evaluation criteria for road construction projects. The decision-making tool is developed by implementing the Analytical Hierarchy Process (AHP) along with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) as a scientific base for the selection mechanism. The selected criteria for evaluation are established through a literature review and expert's opinion in the field. Moreover, the Aggregation of Individual Priorities using the Weighted Geometric Mean Method (AIP-WGMM) is introduced as part of this research to assist in group decision-making through AHP. The established model will be assessed by utilizing the model in a realistic case study. After conducting the case study, the outcomes are compared to the traditional practice in tender awards, which is the lowest price. Based on the results, the bidder awarded the contract that submitted the lowest price came as second after performing the case study using the proposed system.

Keywords: Contractor selection, AHP, TOPSIS, Road construction, Yemen, Tenders, Decision-making, Tender evaluation, Evaluation criteria

ÖZ

İnşaat sektörü ülkelerin en önemli sektörlerinden sayılmaktadır. Yüklenici seçimi, müşteriler veya kuruluşlar tarafından alınan kritik bir karardır ve herhangi bir inşaat projesinin başarmasını oldukça önemli bir rol oynamaktadır. İnşaat sektörü gelişmektedir ve projeler daha karmaşık hale gelmektedir, sonuç olarak geleneksel ihale uygulaması artık uygun değildir ve düşük fiyat uygulamasının yürütülmesinden kaynaklanan sorunlar nedeniyle iyileştirmeye ihtiyaç duyulmaktadır. Aşağıdaki araştırma, yetkin bir müteahhit seçimine yardımcı olacak bir karar verme modelinin geliştirilmesine ve ayrıca yol yapım projelerine ilişkin değerlendirme kriterlerinin oluşturulmasına odaklanmaktadır. Karar verme aracı, seçim mekanizması için bilimsel bir temel olarak Analitik Hiyerarşi Süreci (AHP) ve İdeal Çözüme Benzerliğe Göre Tercih Sıralaması Tekniği (TOPSIS) uygulanarak geliştirilmiştir, halbuki değerlendirme için seçilen kriterler literatür taraması ve alandaki uzmanlar aracılığıyla belirlenmiştir. Ek olarak, AHP aracılığıyla grup karar vermesine yardımcı olmak için Ağırlıklı Geometrik Ortalama Yöntemi (AIP-WGMM) kullanılarak Bireysel Önceliklerin Birleştirilmesi bu araştırmanın bir parçası olarak tanıtılmıştır. Kurulan model, proje için yetkili yükleniciyi belirlemek için gerçekçi bir vaka çalışmasında model kullanılarak değerlendirilecektir. Vaka çalışmasını yürüttükten sonra sonuçlar en düşük fiyat olan ihale ödüllerindeki geleneksel uygulama ile karşılaştırılmaktadır. Sonuçlara göre, en düşük fiyatı sunan ihaleyi kazanan teklif sahibi, önerilen sistemi kullanarak örnek olay incelemesini gerçekleştirdikten sonra ikinci olmuştur.

Anahtar Kelimeler:Yüklenici seçimi, AHP, TOPSIS, Yol yapımı, Yemen, İhale, Karar verme, İhale değerlendirme, Değerlendirme kriterleri

DEDICATION

I dedicate this research with love and eternal appreciation to my deceased grandfather Mr. Fadhl Al-Akwaa who passed away few weeks before this research was finished.

ACKNOWLEDGMENT

I want to express my gratitude to the following people:

Assoc. Prof. Dr. Tolga Çelik for his guidance and assistance throughout the whole research. It has been an honor to be his master's student. I was able to overcome difficulties and obstacles during this research with the help of his wisdom, knowledge, and patience.

Mr. Iman Youssefi for his great contribution in this research. He has a different perspective in which he looked at challenges differently. I was able to knock on his office door anytime, and I am grateful for that.

My parents, Mr. Khaled Al-Akwaa and Ms. Arwa Omar who, raised me to be the man I am today. I am eternally grateful for their love, support, and guidance throughout my life. They are the greatest blessing of my life, and there are no words that can describe the debt I owe to them.

Sami and Omar my big brothers. They have always encouraged me to be the best version of myself, and they have never failed to amaze me. I try to follow their path and be as successful as they are. Of course, I want to thank my nieces, Sama Sami and Nour Omar, for bringing joy and happiness into our lives.

Finally, my other half Luai and the gift to my heart Hadeel. My best friends and roommates who have always shown unlimited love and support. I am very thankful for their presence here with me.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
AIP	Aggregation of Individual Priorities
ELECTRE	Elimination and Choice Expressing Reality Methods
MAUT	Multi-Attribute Utility Theory
MCDM	Multi-Criteria-Decision-Making
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
VIKOR	Multi-criteria Optimization and Compromise Solution
WGMM	Weighted Geometric Mean Method

Chapter 1

INTRODUCTION

1.1 Introduction

Construction, in general, is a very large industry with many disciplines representing a considerable number of the gross domestic product of every nation. Highways and roads, in particular, are essential infrastructures that serve as the backbone of any nation and enable the rapid and safe delivery of goods and people, thus facilitating economic and social development. A nation's growth and development are dependent on its citizens' ability to participate in and contribute to society. Also crucial in the battle against poverty is giving access to jobs, social, health, and education services, making a road network essential. They contribute to the growth of the local population and the increase in employment rates in underdeveloped regions (Kim & Han, 2016). Roads are the veins that carry the blood of the nation's economy in which they are essential to any development strategy because they connect producers to markets, workers to employment, students to school, and the sick to hospitals. In the decade after 2002, According to the World Bank statistics, a number of roads that has built or restored represents more than 260,000 kilometers. More money is loaned for roads than is loaned for education, health, and social services put together(How Roads Support Development, 2015).

Procurement in construction in general and in road construction specifically is complicated by a number of competing quantitative and qualitative parameters or

criteria, such as cost, quality, and delivery time. Thus, Selecting the best contractor is significant and has aroused so much attention lately because roads make a significant contribution to economic development and progress, as well as providing significant social advantages. The contractor selection decision-making issue, on the other hand, includes trade-offs among various criteria that include both quantitative and qualitative aspects, some of which may conflict with one another. As a result, a broad variety of multi-criteria decision-making (MCDM) methods have been developed and have seen widespread use in both theoretical and practical contexts, which will be discussed further in chapter 2. Furthermore, due to the high level of projects nowadays and their complexity rate, it is essential to use a MCDM to evaluate the contractor to have a fair transparent competition among bidders and ensure selecting the best contractor between alternatives (Jato-Espino et al., 2014). Adopting techniques that result in shorter lead times, lower prices, and improved quality is critical for evaluating contractors in the tender evaluation phase. In which the risk of the project is highest during the contractor selection phase because if the wrong decision was made this could lead to bad consequences such as termination of the project due to the contractors financial or technical insufficiency(Cheaitou et al., 2019).

According to the findings of the research, the evaluation process is one of the most critical aspects that has a direct influence on the success of a company's overall performance. Along with the introduced MCDM tools, criteria used to evaluate the contractor are important to address because these parameters are the input data to the MCDM tool. On this basis, the MCDM works. Weights to these criteria should be identified as well to be able to choose between the alternatives. The current practice in most of the developing countries is awarding the contract based on the lowest-price in

which the bid price is the most important and, in some cases, the only criteria to consider, however in today's construction environment this practice does not give effective outcomes in terms of contractor selection(El-Abbasy et al., 2013).

1.2 Background

With a land area of 530,000 km^2, Yemen is the southernmost nation on the Arabian Peninsula. It has 21 governorates, which are further subdivided into 333 districts, and a population of around 28 million people now, according to official estimates. During the first quarter of 2006, the Yemeni government, with the assistance of foreign development partners, unveiled the national reform agenda, which is a comprehensive set of ambitious and interrelated reform initiatives to promote good governance. As a result of the local demands to combat corruption, maximize the use of limited national resources, enhance the lives of residents, and respond to the frequent alarms raised by development partners to reform the public procurement system, the National Reconstruction Authority was established. On December 21, 2000, the World Bank completed a report on the "Yemen Country Procurement Assessment Report," which revealed that several gaps exist in the system, including gaps in the legal, institutional, and transparency & integrity frameworks, in addition to discrepancies with the World Bank's Guidelines(Thabit, 2019).

Furthermore, the road construction industry has not been doing well lately, given the condition of roads constructed not so many years ago are now in a very bad condition, and major highways are closed due to significant damage (Extreme road-building in Yemen: pictures - global construction review, 2021). The subbase of all these corruptions related and poor-quality roads are the wrong choices of the contractor to execute the project and poor tender documents preparation in some cases. According

to a joint study performed by the Organisation for Economic Co-operation and Development (OECD), the Yemeni population lives in about 100,000 settlements, most of which are located across difficult, mountainous terrain because many of these communities do not have access to roads to the network of feeder roads (Enhancing integrity in public procurement in Yemen OECD joint learning study, 2009).

1.3 Problem Statement

According to Law No. (23) of the Year 2007 on Tender, Auctions, and Government Storehouses in the Republic of Yemen (Tender_law_2007 Yemen), a contract shall be awarded based on the lowest price. This has resulted in having a negative impact on the whole tendering practice. There is no definite MCDM tool used to evaluate the bidders in order to choose the best alternative, which, as discussed earlier not effective anymore due to complexity and the level that projects have reached nowadays (Jato-Espino et al., 2014). In road construction, according to the higher tender committee after the prequalification stage, the contractor shall be selected depending on the lowest bid price proposed. This practice is no longer adequate to still be in use. To ensure the best value for money; then a MCDM shall be applied. However, a joint learning study was performed by the OECD based on a request from the Yemen government officials as a part of a national reform agenda, and it was concluded that public procurement in Yemen lacks transparency and integrity and has proposed several proposals to take action.

Furthermore, according to (Khoso & Yusof, 2020), during the past 20 years only, considering highly cited papers, only few papers talked about having specific criteria used to assess a particular type of project, and most of the criteria discussed were general and not easy to evaluate due to many reasons such as, challengeable data to

obtain and the uniqueness of every project so the same general criteria cannot be used which leaves a gap in research. Another thing to consider is the contractor selection problem based on the author's origin, in which it is worth pointing out that Yemen is way behind on this topic because of the crisis going on and the high rate of corruption; therefore, there has not been researched or efforts to enhance the public procurement in the government.

Lastly, it is worth mentioning that (Waara & Bröchner, 2006) published an article that won the best paper of the year that was discussing price and non-price criteria in contractor selection in the construction industry, that have noticed that non-price-criteria such as technical design has never had a prespecified scale to assess the contractor and based on the research carried out in writing this thesis. This gap has not been filled yet. Some papers use a 1-10 scale, which again increases subjectivity because this scale they intend to use is not prespecified.

1.4 Research Gaps

It has been found that the contractor selection procedure involved a number of uncertainties and gaps that authors have been trying to solve in the past decades, which they managed to solve. However, despite the considerable number of articles published and the amount of work done by people in this field it has been observed that there is still an existence of some research gaps.

Firstly in hybrid systems, it was found that some systems were too extreme in a way that impacted the whole hybrid system; in some of the methodology or the MCDM tools, it was found that there is still some space for subjective judgments, which defiantly impact the entire selection process given the influence that one individual

can have on the final decision, criteria weights cannot be fixed for all road projects and it should be flexible like some literature suggested it should depend on the project nature, the number of criteria in some articles was large which makes the selection phase harder, some non-price criteria are hard to evaluate in which there has never been a specific weight to rank these criteria as it was mentioned in (Waara & Bröchner, 2006b) publication which was the best paper in 2006 in the journal of construction engineering and management in which it was downloaded 1250 times and in some cases the number of criteria is high which effect the whole evaluation procedure.

1.5 Research Objective

This study will focus on the following aims and objectives:

1. To identify the required criteria for evaluating contractors for road construction projects.
2. Select those criteria that could practically be employed for the contractor evaluation process.
3. To identify the methodology for the selection of contractors for road construction projects.
4. Select those flexible approaches that could generate accurate results based on their cons and pros.
5. To develop a novel contractor selection framework compared to traditional approaches for contractor selection that encourages transparency and mitigates subjectivity in decision making.
6. To examine the applicability of the proposed framework using a real-life case study.
7. To define criteria weights depending on the nature of the project using a defined tool that limits subjectivity.

1.6 Research Questions

The following research questions have been prepared in order to fulfill the mentioned objectives:

1. What are the various procedures for evaluating tenders?
2. What are the various tender evaluation criteria?
3. What is the weightage of evaluation criteria?
4. What techniques are adopted for the assessment of tenders in Yemen's road construction industry?
5. What are the present public tendering problems in Yemen road construction?

1.7 The Scope of the Research

As previously stated, the primary goal of this study lies in strengthening Yemen's construction sector tendering-wise, precisely in the area of road construction tenders. The scope of the thesis offered here, like any other research study, is defined by the research objectives listed in section 1.5. The evaluation of road construction tenders and the evaluation criteria under the public procurement act is the subject of this thesis. This study relies heavily on the literature review, a case study, and past research done in accordance with subjects. It's important pointing out that the literature review that is used as the base of this study is of highly cited papers. This research does have certain constraints, especially when it comes to the case study because of some exceptional conditions, such as safety concerns (civil war), technological, time, and Yemeni government operational indicators. The public in the north and south areas is the focus of the study, with Sana'a serving as the research's base.

1.8 Thesis Structure

Chapter one ‘Introduction’: The introduction to this thesis identifies the problem, contractor selection, and criteria evaluation, which will be the central focus of this research, provides a brief background about the issue in Yemen and the importance of selecting competent contractors for road construction projects.

Chapter two ‘Literature Review’: The second chapter's primary objective is to compile publications and efforts of the prior research and works that are relevant to the topic of this research. The earlier studies had some influence on the more broad approaches to decision-making based on several factors. In addition, different MCDM tools used for tender evaluation and determining the important criteria for contractor selection were the focal points of the research.

Chapter three**:** ‘Research Methodology’: The third chapter is going to examine the research technique that was used in the study as well as define the strategies that were used to decide the criteria. Along with The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique, the Analytical Hierarchy Process (AHP) will be analyzed and deconstructed in great depth with consideration of its group decision-making technique. To establish the evaluation criteria, considerations were given to the thoughts of researchers and the conclusions they reached, as outlined in the earlier study. This section discusses the calculation process in detail to simplify the comprehension of the results attained later in chapter four.

Chapter four ‘Case study’: In this chapter, the AHP and TOPSIS models are utilized in order to propose and test a model for the selection of contractors. The relative weights would also be determined from the pairwise comparison matrices that were

used, but this could not be performed due to some reasons and thus considered as one of the study's limitations. A sample problem for the selection of contractors was brought up so that the validity of the model that had been developed could be examined. The issue was composed of six different contractors, and it was then organized into a model and carried out in parallel. The results that were acquired were compared to one another and openly discussed.

Chapter five ‘Conclusion, Recommendations and Future Works’: The last chapter of this thesis was all about figuring out what the most important things were that were learned from doing this study. Recommendations will be made about how to use the established contractor selection model and what work should be done in the future.

1.9 Summary

Chapter one has given an overview of the research study as a whole. This included the goals and objectives, as well as the problem and why it was important. In this chapter, we also looked at an overview of the research. The chapter concluded with thesis guidance. The upcoming focuses on the literature review related to the research topic.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of basic facts about construction assessment of bids, the history of approaches for selecting contractors, and the selection criteria adopted in construction sector. First, the tendering process in the construction industry, with a focus on the public sector, will be presented, followed by an introduction to the core components of contractor selection and related processes. Construction contractor selection-related issues such as evaluation procedures and assessment criteria will be presented to offer a better understanding of the many aspects that go into selecting a contractor through examining the benefits and drawbacks of different methods, as well as current difficulties that must be addressed in the course of the research in terms of evaluation criteria.

2.2 Tendering Process

The major tender procedure in the construction industry is frequently for selecting the contractor who will carry out the construction work according to the tender specifications agreed by both parties (Roy, 2017). Contractor selection and bid evaluation is still a very important and interesting topic for organizations in charge of getting work done, and this is likely to continue (Watt et al., 2009). So many papers and researchers have been published in the last 20 years, and this topic is still a research topic that grabs so much attention by today’s researchers. The evaluation of the tender process takes place early in a project's phase and is one of the most vital jobs the project

owner must complete. Performing a thorough investigation of the contractor, tender review process, and tender review methodologies is hard and requires a lot of time that is an endeavor fraught with many uncertainties (Watt et al., 2010). It is confirmed by (Bochenek, 2014) that the process of selecting a contractor for construction work is a time-consuming and challenging process that is dependent in large part on the tender requirement's adequate preparation, in which all of the tender's requirements must be clearly defined.

When it comes to the majority of situations, providing an insufficient explanation of the tender specification raises the probability that the chosen contractor will be unable to fulfill the needs of the project. For making an offer on a contract, a potential supplier must first respond to an invitation to tender by sending in a written submission. The contractor submits a proposal for the provision of products or services.

There is a lot of misunderstanding in the industry about the differences between tendering and procurement. The terms are sometimes used interchangeably without any consideration given to their actual definitions. The activities involved in the construction process are distinct in nature, and it is necessary to have a thorough understanding of them in order to explain the differences. According to (Graner, 2014):

- Procurement is the entire process of getting products and services from external sources (for example, a building contractor). It involves determining the strategy for acquiring such items by analyzing the client's criteria (for example, time, quality, and cost), as well as their attitude to risk.
- Tendering is a crucial part of the procurement process, but procurement is about much more than getting a price. Tendering refers to both the bidding procedure and selecting a contractor.

2.2.1 Invitation to Tender

In the usual course of business, the client's responsibility iso publicize their project's openness to potential bidders (Bennett, 2003). Clients often issue an invitation to tender (ITT) or advertise for tender in public and private projects by giving basic information about the project in a document that serves as either an invitation to tender or an advertising for tender. It is common for tender information to include the tender date and time, the location of the tender, and the cost of the tender, which may include an initial deposit. A breakdown of the project scope, key materials, and a budget estimate should also be included in the invitation.

However, various methods, including the media, email, and postal mail, have been used to invite interested contractors to submit bids.

2.2.2 Tender Form

(Bennett, 2003; Plebankiewicz, 2009) Explains that the content on the contract form is often determined by the contract's category. Furthermore, if the client expects a lumpsum contract, the tender form will be straightforward, containing only a single price and other details, as opposed to more complicated forms. If the contract is of the unit price, measure, and value type, there must be areas specified for the declaration of unit pricing corresponding to the different bid elements. This is required if the contract is of the unit price, measure, and value variety. It is likely that the tender documents will include a request for schedules of rates and time charges, as well as a description of the resources and overheads that will be practiced, and it is also likely that the names and contact information of any prospective subcontractors or sub-consultants will be included in the tender documents.

2.2.3 Tender Types

There are three main types of tenders:

1- Open tendering:

Participation and submission of a tender are made possible through this method for contractors who fail to meet the essential requirements(Ashworth, 2008) . If the number of tenders received exceeds a certain threshold, ineligible contractors are removed from the list(Ashworth, 1998). Contractors can submit their bids for a project through an open tendering process, which allows them to compete against one another. The client provides a brief description of the project; after that, eligible individuals are invited to to submit their bids to be evaluated (Bennett, 2003).

2- Selective tendering:

Which is also referred to as the “classic system," and it continues to be the most widely used method of awarding construction contracts. The number of companies participating in this method is, in most cases, less than six participants, and the project team only invites a small number of well-known companies that have been carefully chosen (Ashworth, 2008). Only a pre-determined list of organizations are invited to submit bids in response to the call for tender. Selective tender starts with an invitation to two or more organizations. A closed tender has the advantage of being simple and easily prepared, which is effective. When a closed tender is used, its weakness is always the public’s dissatisfaction with the decision to keep it closed.

3- Negotiation tendering:

Alternately, the construction tender negotiation approach might be used in place of the traditional tendering process. Assuming that the customer has adequate knowledge of the construction sector especially in the field that the project is related to. In this instance, the client's agent may ask one firm to submit an offer and a proposal,

following the involved will discuss the terms of the contract. If the negotiation goes well, the contract's construction will be completed. If not, another executor may be asked to submit a proposal, and the process may be repeated (Bennett, 2003). As part of the bidding process, the parties to a deal have the option to negotiate all aspects of the bids (Graner, 2014). In most cases, this takes place when a client contacts a certain contractor based on the contractor's reputation or an existing connection, and the client and contractor then negotiate the terms of the agreement (CDM 2015 – Designing Buildings, 2022).

2.3 Background of the Public Procurement Process in Yemen

During the tendering process, all bidders must be aware of and follow any directions issued by the Yemeni government and any other guidance papers contained in the call for bids and other materials supplied to them. However, suppose any participant has bribed or is suspected of bribing any of the officials who has the capacity to influence the decision of the winner of the tender or having any personal relationship with any of the tender committee members. In that case, the committee asking for tenders has the discretion to disqualify them from the process. The bidder who wishes to participate in a tender must present an initial bond which is referred to as participation bond that the committee has determined, and this bond will remain in effect until the final contractor has been picked. When restrictions are broken, such as accepting a bribe or failing to answer to a committee request, the bond is revoked. When making an offer, it is essential to include all of the expenses associated with the tender in the offer. These costs may include the cost of paperwork, delivery, purchasing, insurance, and customs duties. The prices on the tender must be written in both characters and numbers, and they must be stated in Yemeni riyals. The prices must also be documented on the tender paper.

Moreover, if the contractors fail to include or do not include the pricing fees for any things in their proposal, the bidder's proposal will be regarded as incomplete, and he will be requested to fix it before it is accepted. According to the tender documents, a bill of quantities table is supplied as most of the contracts are unit price contracts, and the bidder is required to fill out this table in order to get the amount. As previously said, the costs should be written in Yemeni riyals and must be expressed in numerical and alphabetic manner. Bidders aren't allowed to violate or change any of the characteristics of the items they put in for consideration. Visiting the construction field before submitting the bid is recommended to be done by the contractor in order to analyze the present situation and gather all necessary information in order to provide a realistic price.

Lastly, a quality bond is presented for the contractor who is awarded the contract so that, in the event of any quality deviations, the bidder is compelled to rectify them; if he refuses, the committee has the authority to utilize the quality bond for preserving the intended level of excellence. This quality bond is usually 10 percent of the total project cost.

2.4 Overview of Contractor Selection

The construction sector is growing at a quick pace and has become increasingly competitive. In order to assure the effective execution of the project, technological advancements must be matched by improvements in the procedures used for procurement applications. (Khoso & Yusof, 2020). A vital step in guaranteeing the timely and profitable completion of construction projects is the formulation of a comprehensive, well-documented procurement strategy that is based on in-depth research (Morledge & Smith, 2013; Watt et al., 2009). However, throughout the

project's early phases, it has been proven in most papers that the contractor selection process is the most important step in the construction procurement process(Darvish et al., 2009; Rashvand et al., al., 2015). According to (Martin et al., 2018)the majority of clients see contractor selection as the most significant factor in the delivery strategy for construction projects. Selecting the most qualified contractor has the capability to increase the potential of completing the proper project on schedule and with sufficient quality by as much as 50%(Chiang et al., 2017; G. Holt, 2010; Rashvand et al., 2015). An adequately handled tender procedure enables the avoidance of a variety of difficulties that may arise during the project's implementation phase(Lam et al., 2009). Successful project delivery will be more likely if the bidding process is carried out correctly and is based on a thorough review of all bids. Due to the fact that tender assessment problems are multi-criteria in their formulation, developing an appropriate model is difficult. (Sonmez et al., 2001) developed a model in which customers must make a decision between competing goals and restricted resources. More complicated projects necessitate the need the consideration of a larger number of variables, requiring the use of more complex methods at a higher level of abstraction.

2.4.1 Key Components of Contractor Selection

In its most basic form, contractor selection consists of three procedures: pretender, prequalification, and tender review. Nevertheless, each of these strategies is adaptable to a diverse selection of different procedures that may differ from a country to a country or from an organization to another based on the followed regulations. Although numerous public tendering methods exist, major components of contractor selection include setting project objectives, selecting an assessment technique, and establishing evaluation criteria that help in selecting an appropriate contractor to execute the work associated with him.

2.4.1.1 Pre-Tender

The contractor side of construction projects continues to have a high rate of failure due to a variety of factors, including, but not limited to, financial issues, poor management, and overcommitment (Doloi, 2009). The primary purpose of the prequalification process is to reduce the number of contractors who are qualified to participate by screening out candidates who do not meet the requirements which are set by the tender committee (Ksiazek & Ciechowicz, 2016). Pre-qualification is an important aspect of the construction requirement. If the pre-qualification procedure is followed appropriately, it is possible to reassure customers that the contractors who have been shortlisted have a good chance of bringing the project to a successful conclusion(Abdelrahman et al., 2008; Jafari, 2013).

Prequalification is an essential step in complicated and high-priced projects, and it is equally important for clients and contractors since it aims to get the most outstanding value (G. Holt, 2010). Contractors may also find this technique helpful in assessing which components of the organization are strong and crucial and which areas have potential for improvement. According to (Palaneeswaran & Kumaraswamy, 2000), some pre-qualification goals include the following:

- Get rid of contractors who aren't responsive, reliable, or skilled.
- To improve and ensure the availability of bidding possibilities for contractors who are "eligible".
- To generate a sense of friendly competition among the contractors who are "eligible".
- To reduce the odds of a failed contractor job and to increase contentment among customers.

- To discover the optimum price-performance ratio in the contractor selection process.

2.4.1.2 Evaluation of Bids

Cost and time overruns, serious issues with quality standards, safety measures, rising number of claims, counterclaims, and lawsuits define the construction situation in many parts of the world. As a result of these concerns, the total number of claims, counterclaims, and litigation has increased. (Chan et al., 2002). The most important issue that any construction client must overcome is choosing an acceptable contractor who will complete the project in question in accordance with the specifications; different authors agree that the evaluation and selection phases in a tender are crucial. Doing so will help minimize or maximize the impact of these hazards(Chiang et al., 2017; Darvish et al., 2009; Doloi, 2009).

Formulation of the decision-making problem, on the other hand, involves several criteria. It includes a variety of factors, and it requires customers to make decisions between competing aims and limited resources. Previous research has demonstrated that a significant number of construction project failures may be traced back to a lack of efficient tools that are used to appropriately evaluate contractors prior to the awarding of the contract (Darvish et al., 2009; Kashiwagi & Byfield, 2002; Zavadskas et al., 2008). According to (G. Holt, 2010), these tools exhibit a wide range of variability and are characterized by non-linearity, ambiguity, subjectivity, and volatility. The rate at which new information may be taken directly influences how successfully these strategies function. The selection is highly preferred to supported by sophisticated decision-making mechanisms, which take certain assessment factors into account. mainly when working with complex projects. In this context, (Hashemi

et al., 2018) believes that the MCDM technique is the most suitable strategy, in particular for selecting contractors. The selection of the contractor in the past involved the use of a number of decision-making strategies, of which some of the most critical instruments will be described in further detail later in this chapter.

2.4.1.2.1 Lowest-Price

There are many practices and methods followed in selecting the contractor, but the most followed and implemented in the public sector is the lowest price which basically awards the contract to the lowest bidder. However, this may result in the selection of unqualified contractors rather than qualified ones and the acceptance of others who are unable complete the project successfully. The 'lowest bidder' criteria for selecting a contractor were found to be inadequate in assessing tender evaluation procedures from across the globe. Numerous counties have implemented qualifications for this criteria and formed assessment methods in response to this shortfall. The goal of the criteria is to ensure that a qualified contractor is chosen while promoting competition. Adopting an MCDM strategy is the key solution to this event (Oladapo & Odeyinka, 2006). Some claim that this strategy delivers the highest level of public accountability in the public sector since the lowest price is shown to be acquired in an open and fair competition. However, in the public sector, what is truly needed is not only the lowest price but the most outstanding value for the money spent, and there is much question over whether this can be accomplished by merely choosing the lowest price in a completely unconstrained free market (Smith, 1995).

Furthermore, there may be serious consequences regarding poor quality, delays and additional costs due to rework, and a preponderance of claims and disputes. Members of the tender board or tender committee tend to choose the contractor based on the

lowest price because procurement personnel is typically held accountable for their decisions, and selecting the lowest is easily justifiable. Therefore, selecting a contractor other than the one offering the lowest price becomes extremely difficult (Abdelrahman et al., 2008.). According to previous research, one of the causes having trouble such as poor performance in the process of executing projects by contractor is ineffective contractor assessment systems (G. D. Holt, 1998). It has been well acknowledged for many years that the construction industry has considerable challenges when it comes to selecting the best-qualified contractors for certain projects (Darvish et al., 2009; G. Holt, 2010). For decades, the assessment criteria for tenders have remained essentially constant (Darvish et al., 2009). In public procurement, contractors being selected according to their ability to provide the lowest price remains the prevailing bidding strategy (Hatush & Skitmore, 1997; G. Holt, 2010). Many papers and studies have been criticizing selecting the contractor based on the lowest price. Yet, this selection parameter is still the current practice in a considerable number of countries such as Yemen (Tender_law_2007 Yemen). Selecting the contractor based on the lowest price award criteria opens a gap for corruption and affects the evaluation of the contractor based on qualitative specifications. Furthermore, the public procurement in Yemen is facing a high corruption rate due to many reasons, according to a joint learning study done by the OECD that was requested by the government as a reform agenda to fight corruption (Enhancing integrity in public procurement in Yemen OECD joint learning study, 2009) public procurement in Yemen needs reformation and adoption of different evaluation methods that increase public procurement integrity. Dr. Mohammed Thabit published a paper about the public procurement in Yemen suggesting a number of key recommendations that mentions developing a relevant procurement and increasing integrity(Thabit, 2019).

2.5 Some of the Most Known Methods for Contractor Selection

2.5.1 Dimensional Weighting Method (DWM)

The dimensional weighting technique bases the selection of each criterion and its significance on the decision-makers and their preferences. This is true regardless of whether the decision-makers are the owner or the consultant. When utilizing dimensional weighting, the overall rating of the contractor is computed by adding up the rankings of each criterion and then multiplying that total by the weight associated with that criterion. After that, the contractors are ranked according to their overall scores, and the prepublication uses this ranking order of the contractors (Al-Harbi, 2001; Sonmez et al., 2001). However, the primary benefits of using the DWM are that it is easy to implement, and one does not require any specialized expertise in order to comprehend it. The DWM model has a flaw in several vital aspects that need to be addressed. To begin, the DWM is reliant upon the arbitrary and personal opinions of the individuals who make the decisions. Second, if you have a good score in one category but a poor score in another, you can make up the difference. Third, the concerns that are connected to the inconsistent data provided by contractors are not taken into consideration. Fourth, the concerns that arise from having a variety of decision makers' opinions are not taken into account. Lastly, it is impossible to accommodate many criteria, each of which uses a different unit of measurement.

2.5.2 Multi-Attribute Utility Theory (MAUT)

The Multi-Attribute Utility Theory, also known as MAUT, is widely regarded as one of the most important approaches to decision-making that takes into account multiple criteria, and it has proven to be an effective tool with international applications for addressing real-world issues of a complex nature. In a different research study (Pohekar and Ramachandran, 2004), the MAUT technique was utilized as a form of

multicriteria making a choice to evaluate renewable energy planning. They demonstrated that the MAUT method is useful for assisting decision-makers in determining the significance of outcomes by evaluating the outcomes in terms of numerous qualities and combining completely separate tasks to generate as a whole utility values. This was accomplished by assessing the significance of the outcomes in terms of numerous qualities. The findings indicate that MAUT is not utilized in energy planning to a very significant extent. This might be owing to the need for an interactive decision environment that is necessary for the formulation of utility functions, or it could be related to the complexity of finding scaling constants when utilizing the technique.

It should be noted that MAUT is not promoted as a solution. It has advantages and weaknesses, just like any other system or approach, and they have been pointed out. (Kahraman et al., 2009; Sanayei et al., 2008; Sonmez et al., 2001; Teixeira de Almeida, 2007). MAUT is able to deal with a variety of contractors, which is one of its many advantageous features. Additionally, it is able to handle unclear data, which includes the risks that a decision-maker could take, which is another advantage of this method. In addition to this, it is especially important due to the fact that it enables the examination of both qualitative and quantitative criteria, as well as the ability to take into consideration a large number of stakeholders. Despite these benefits, MAUT is constrained in several aspects, and there are circumstances in which its use is impossible. This approach throws a significant load on those in charge of making decisions since it requires them to answer a huge number of hypothetical questions in the style of a lottery in order to learn about their true preferences. This is one of the method's primary flaws. Another drawback of MAUT is that the process of calculating

judgments may be irritating and time-consuming if there are many different criteria to examine. Furthermore, rationality is one of the theory's main needs, which incorporates compensation as one of the criteria. In order to get a synthesis multi-criterion utility function, this reasoning also need the method of aggregation of all criteria. The individual making the decision does not always examine this type of logic. It's possible that the logic of the decision-maker calls for a non-compensatory approach. Last but not least, MAUT is unable to cope with several decision-makers at the same time since it lacks the capacity to do so.

2.5.3 AHP

The Analytic Hierarchy Process, often known as AHP, has its foundation in the precise mathematical structure of highly credible matrices and the capacity of their related right eigenvectors to provide an exact or approximative weight for each element in the hierarchy. In addition, the AHP is a MCDM tool that employs hierarchical structures to define a selection issue, and then the weight of the sub-criteria is established or alternatives depending on the decision maker's judgments throughout the system. This method is also known as the Analytic Hierarchy Model (AHM). It addresses how to frame a difficult selection problem, define its criteria, quantify the interaction among them, and, finally, synthesize all of the information to arrive at weights that express preferences (T. L. Saaty, 1988) By systematically analyzing vast quantities of qualitative and quantitative data and criteria using a variety of criteria, the AHP gives decision-makers the ability to transform a complicated issue into the form of an indication. Because of this, the difficulty of the situation might be seen as being more manageable. Through the process of constructing and analyzing a series of pairwise judgmental comparison matrices, this method also makes it possible for a decision-maker to build an implicit trade-off among various criteria. This is made possible by

the fact that the decision-maker is able to build an implicit trade-off. The AHP is an approach to problem-solving that involves analyzing judgments and resolving disputes through a process that involves evaluating the relative weight of a set of activities or criteria. The AHP may accommodate both objective and subjective considerations within the framework of collective decision-making, as well as individual and combined values (Chen, 2006).

The AHP, much like the other approaches that was discussed before, has a variety of advantages and disadvantages; however, the positives appear to exceed the limits of the method. According to (Mahdi et al., 2002), the capacity of the AHP to evaluate available options in order of how effectively they may be used to accomplish competing objectives is its most important feature. This is considered to be the AHP's primary strength. These authors also highlight the fact that the strategy is straightforward and quick to use, as well as the fact that it enables fast replanning. Along with this, the AHP can take qualitative and subjective aspects into account. AHP is also helping the employment of a structural model scale to quantify management decisions. Another advantage of using this technique is that it has a well-designed methodology, which makes it possible to measure the degree to which these judgments are consistent with one another via conducting a consistency check. Having said that, it seems that the technique has one significant flaw, as pointed out by (Mahdi et al., 2002). This constraint is based on the fact that in order for the procedure to be successful, all of the matrices need to have the same mathematical structure, which is referred to as a positive reciprocal matrix. Lastly, AHP is not the best approach for scoring more factors in building projects, particularly if they are not independent of one another (Semaan & Salem, 2017).

2.5.3.1 Group Decision in AHP

It is common practice to apply the Analytic Hierarchy Process, often known as AHP, in settings involving groups of people who either engage in discussion with the goal of reaching a consensus or expressing their own views. A variety of aggregation strategies can be applied to separate opinions. The Aggregation of Individual Judgments (AIJ) and the Aggregation of Individual Priorities (AIP) are two of the methodologies that have been discovered to be the most helpful because many other approaches have been introduced, but AIJ and AIP have been tested and used in real-life scenarios (Krejčí & Stoklasa, 2018). Based on past research, it was suggested by some authors that the choice of approach is dependent on whether the group is supposed to behave together as a unit or as independent people, whether it satisfies the social axioms, and how effective it is in the desired field it is intended to be applied. They go on to explain why AIJ is appropriate for the former scenario while AIP is suited for the latter scenario. The scientific literature has a number of alternative proposals for aggregation techniques; nevertheless, the geometric mean is the one that is used the most commonly. There are numerous other procedures that have also been presented. This is because it's the only separable synthesizing function that can meet all three requirements: unanimity (the Pareto principle), homogeneity, and reciprocal properties (i.e., the reciprocal property) (Escobar & Moreno-Jiménez, 2007).

Furthermore, (Ossadnik et al., 2016) conducted thorough research on past literature review in the group decision-making context, and they did 4 case study scenarios to test four different AHP group decision approaches; among these is the AIP and the AIJ. He also tested them in relevance to social axioms. However, he concluded that the AIP procedure offers the best way to meet relevant rationality axioms with the least

amount of time and effort. It works well for both small and large groups, as well as for situations where people want different things. The weighted geometric mean method (WGMM) version of AIJ may also be recommended if it can be assumed that the people making decisions will put their own needs aside in favor of a small, similar group. Its arithmetic version, on the other hand, can't be used. Despite the fact that the AHP group model employs a great deal of the information that is already accessible, it is mostly only useful for small groups and problems with clear structures. So, the AIP is still the best aggregation method among the AHP and Analytical Network Process (ANP) for helping a small group of experts solves very hard decision problems. AIP has a significant amount of promise for supporting choices with contrasting or competing objectives. In light of the fact that the AIP weighted arithmetic mean method (WAMM) is incapable of ensuring that the power criteria are satisfied, the AIP weighted geometric mean technique (WGMM) is an even better option for providing rational group decision support.

2.5.4 TOPSIS

TOPSIS was the first technique that was offered for putting performance in order by how similar it is to make an ideal solution. It was presented in 1981 as a novel way to handle the issue of MAUT decision-making (Mohammadi et al., 2011). It is a method that ranks various projects according to various criteria based on a comparison and evaluation of a large number of projects (Jiang & Yan, 2010). All of the following authors—(Amiri, 2010; Hung & Chen, 2009; Shih et al., 2007)—discussed a number of the benefits that the TOPSIS offers. The fact that TOPSIS logic is a comprehensible model is one of the significant benefits of this technique. It has excellent computing efficiency, and the procedure is not complicated in any way. One more of its many advantages is that it may provide a straightforward mathematical representation of the

relative performance of the various alternatives. In addition to this, the TOPSIS technique allows for a significant deal of flexibility when defining the options set. The approach is able to choose the optimal option in a short amount of time, and it is simple to add to, delete from, and enlarge the TOPSIS matrix. Finally, in this system, faults may be checked for. Similar methods are introduced, such as Multicriteria Optimization and Compromise Solution (VIKOR), but TOPSIS is the most widely known and easily implemented (Khoso & Yusof, 2020).

2.5.5 Fuzzy AHP (FAHP)

The AHP and Fuzzy-AHP approach both verify that the decision-maker's assessments are consistent with one another. With the use of these systems, the qualitative ratings given to qualities may be translated into numerical numbers. The approaches also have the capacity to deal with scores that have been determined by a group. This method, on the other hand, is unable to take into account the unpredictability of the preference ratings when ranking the contractors. This issue may be circumvented by employing the fuzzy scale, which is a component of the fuzzy AHP that decision-makers use to rank their alternatives. This scale lets people who make decisions say what they think in terms of a range of values. However, according to (Hosny et al., 2013; Jaskowski et al., 2010), fuzzy AHP requires a lengthy learning process in order to comprehend and acquire a comprehensive understanding of mathematical and probabilistic models. In some cases where criteria are well defined and established, the use of the fuzzy AHP method might have a negative impact where it can cause confusion in ranking alternatives. According to (Liu et al., 2016), the fuzzy models in contractor selection have a variety of drawbacks; for instance, this strongly relies on the opinion of experts, which might lead to conclusions that are biased. Due to the fact that fuzzy logic contains reasonable reasons and takes into account the uncertainty elements.

2.5.6 Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

In MCDM problems, the PROMETHEE is an useful tool for evaluating the various solutions. Preference functions that are used in judgements to assign differences between choices are characteristic of it (Abdullah et al., 2019). There are two ways to use PROMETHEE, and they were both invented by (Mareschal et al., 1984). There are at least three advantages to the PROMETHEE according to (Ülengin et al., 2001). The simplicity of the outranking method is the first advantage. PROMETHEE's second advantage is its ability to successfully resolve real-world planning challenges. The fact that PROMETHEE is a full-ranking system is an added bonus. In PROMETHEE I and PROMETHEE II, alternatives may be rated in partial or in whole. A partial rating is achieved by using PROMETHEE I and a complete ranking is achieved by using PROMETHEE II. However, (Jato-Espino et al., 2014) asserted that this procedure is time-intensive, and (De Keyser & Peeters, 1996) stated that this method has been criticized in several ways:

1) PROMETHEE methods may only be used with criteria where the differences between evaluations are meaningful
2) When generating the outrank relations of PROMETHEE techniques, it is not viable to account for discordance
3) By adding or removing an action, the relative position in the preorder between two actions may be altered. Adding or removing an action that is overshadowed by the others

2.5.7 Elimination and Choice Expressing Reality Methods (ELECTRE)

The ELECTRE assessment approach is generally known as a high-performance policy analysis tool that incorporates both qualitative and quantitative criteria to provide high-

quality results. However, a significant benefit of this assessment technique is its ability to determine the precise requirements of a decision-maker and to provide an acceptable evaluation methodology to meet those requirements. It is necessary to illustrate the importance of changed assessment criteria by using the discordance indices of the modified ELECTRE evaluation technique. When used in conjunction with case simulation, the ELECTRE II assessment technique aids in identifying and quantifying the possible consequences of differences in maximum differentiated performance and the sum of differentiated performance under two separate discordance index evaluation criteria. When the ELECTRE assessment technique is used in the absence of a differentiation process, it is possible to get conclusions that are completely opposed to those sought by a decision-maker (Huang & Chen, 2005). Following the development of this method, a number of further versions were developed, such as ELECTREII and ELECTREIII. The core notion of this strategy is based on outranking relationships as well as ideas of concordance and discordance. The outranking relationships are examined using a concordance and discordance indices, which are calculated using this procedure. However, one major drawback of this method as (Sabaei et al., 2015) claimed, is: "The drawback of ELECTRE's regular ranking is that it necessitates the introduction of an extra threshold, and the alternatives ranking is reliant on the magnitude of this threshold, for which there is no one "correct" figure".

2.5.8 Hybrid Models

What is meant by hybrid models is combining two or more MCDM tools in order to have enhanced properties and a more solid tool in hand that serves in the selection phase of procurement. The application of MCDM methods in combination offers a number of significant benefits. After integrating the individual techniques in the appropriate manner, the specific approach may then be employed to positive effect.

On the other hand, it is very necessary to keep in mind that the selected method in the combinations more linked to the goals of the problem. In addition, the use of such a fresh approach would not result in the process being more complicated and unclear. According to (Khoso & Yusof, 2020), Hybrid systems have become increasingly popular as a solution to a number of issues that have arisen with traditional decision-making procedures. This is due to the fact that traditional decision-making methods are not sufficiently comprehensive to deal with all of the problems on their own. The fuzzy AHP, Fuzzy set, and TOPSIS all have a share of 28.5 percent of the total papers related to hybrid approaches, while the VIKOR method has the highest number of articles overall, accounting for 42.5 percent of the total. Therefore, these two strategies are adaptable and have a wide range of applications in the field of contractor selection(Khoso & Yusof, 2020). (Hashemi et al., 2018) implemented a novel method by merging various hybrid techniques for the evaluation of contractors, in this context his model tend to be an extreme hybrid model since it includes four MCDM tools . For the purpose of evaluating contractors, (Senthil et al., 2014) suggested a hybrid technique that makes use of both fuzzy TOPSIS and AHP. (San Cristóbal, 2012) evaluated the TOPSIS method and the VIKOR method for the purpose of evaluating the contractors and discovered that both approaches produced the same findings. Lastly, the number of hybrid models has been increasing lately since combining two techniques might lead to a better system to use, but this could also lead to the opposite result since an easy system is needed in able to be used by people and not be obligated to call an expert in order to use the system.

However, the above-mentioned methods pros and cons are summarized in the following table.

Table 2.1: Summary of methods cons and pros

Name	Advantages	Disadvantages	Author(s)
Dimensional weighting method (DWM)	1) Fast and easy to use 2) Does not need an expert to implement it	1) Encourages subjectivity 2) Different parameters with different units cannot be assessed using this method	(AlHarbi, 2001) (Sonmez et al., 2001)
Multi-Attribute Utility Theory (MAUT)	1) It is able to handle unclear data 2) Works with each decision maker individually to get accurate preferences	1) Involves huge number of hypothetical questions 2) Process of calculating judgments may be irritating and time-consuming 3) Unable to cope with several decision-makers at the same time 4) Involves subjective judgments	(Kahraman et al., 2009) (Sanayei et al., 2008) (Sonmez et al., 2001) (Teixeira de Almeida, 2007)
Analytic Hierarchy Process (AHP)	1) Judgments can be checked 2) Best weightage method 3) Well-designed methodology 4) Most method used in construction field	1) Involves huge number of pairwise matrices 2) Unable to cope with several decision-makers at the same time	(Mahdi et al., 2002) (Semaan & Salem, 2017) (Khoso & Yusof, 2020)
Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)	1) Straight forward, quick and easy to use 2) Provide an easy mathematical representation of the relative performance of the various alternatives 3) Well-designed methodology	1) Uncertainty in obtaining the weights	(Jiang & Yan, 2010) (Amiri, 2010) (Hung & Chen, 2009) (Shih et al., 2007)
Fuzzy AHP (FAHP)	1) This allows to use a wider scale instead of the 1-9 scale used in AHP in which its employees fuzzy scale. This scale lets people	1) This can cause confusion in ranking alternatives and it relies heavily on expert opinion	(Hosny et al., 2013) (Jaskowski et al., 2010)

	who make decisions say what they think in terms of a range of values	2) It requires a lengthy learning process in order to comprehend and acquire a comprehensive understanding of mathematical and probabilistic models	(Liu et al., 2016)
Preference ranking organization method for enrichment evaluation (PROMETHEE)	1) Allows partial and full ranking 2) Effective outranking tool	1) Time consuming 2) Elements are dependent 3) No defined weights 4) Not easy to implement requires prior knowledge or expert	(Ülengin et al., 2001) (De Keyser & Peeters, 1996) (Jato-Espino et al., 2014)
Elimination and choice expressing reality methods (ELECTRE)	1) The ability to determine the precise requirements of a decision-maker	1) The drawback of ELECTRE's regular ranking is that it necessitates the introduction of an extra threshold 2) When this assessment technique is used in the absence of a differentiation process, it is possible to get conclusions that are completely opposed 3) Very hard to implement	(Huang & Chen, 2005) (Sabaei et al., 2015)
Hybrid Models	1) After integrating the individual techniques in the appropriate manner, the specific approach may then be employed to positive effect.	1) Extreme hybrid models result in having negative effect	(Khoso & Yusof, 2020)

2.6 Review and Clarification of the Selection Criteria for Contractors

The procedure of picking a contractor is one that is used regularly and serves the objective of locating a steady supply of competitive, competent, and capable contractors from whose bids may be asked. By ensuring that only qualified contractors are hired to carry out the job, it can make it easier for public and private owners to achieve their goals of success (Mills, 2011). (Cheng & Li, 2010) came to the conclusion that using the wrong methods will have a big effect on how well the project does as a whole, which in turn will have an effect on the selection of the contractor. It is claimed that choosing a suitable contractor is the most crucial issue for clients because of the enormous significance of building projects across nations and the function that contractors play as the most significant executive agents (Hatush & Skitmore, 2010). Therefore, the most important factor to consider when selecting a professional executor is whether or not he possesses distinctive abilities and sound judgment. If the wrong option is picked, it might not only result in a negative relationship between the client and the contractor, but it could also cause the project to fail. On the other hand, the vast majority of previous researchers agree that a selection of contractors based on price merely is not an effective method for picking the most qualified contractors who are able to carry out projects profitably and achieve winning outcomes. Choosing the proposal that is the submitted least cost will almost always result in delays, cost overruns, and quality that is below equal. It can also occasionally drive a project to its end through the escalation of disputes and claims (Wardani et al., 2006). The decision-makers who are responsible for delivering project outcomes continue to view the selection of contractors and the evaluation of tenders as an area that is both important and interesting. It happens early on in the life cycle of the project, and it is perhaps one of the most significant tasks that clients perform. The

success of this effort is directly tied to the success of the project, as well as the achievement of the goals that were stated (Watt et al., 2010).

According to past literature reviews (Liu et al., 2016, Taylan et al., 2017, Cheaitou et al., 2018, Semaan & Salem, 2017, Khoso & Yusof, 2020, Araújo et al., 2019) related to this topic, the Major criteria that are used for contractor selection are as follows:
Experience: Using this criterion, companies are judged not only on their total experience, but also on the experience of their technical and non-technical staff. In the end, the experience was broken down into two different categories: one that was general, and one that was specific to a certain project. A person's prior performance is intimately linked to experience, and it reflects previous successes, previous failures, and the historical monitoring of successful projects.

Personnel/Management capability: It is a term that refers to the technically trained employees who are engaged by organizations. Clients are searching for companies that have a wide talent pool with a great deal of experience when it comes to critical personnel positions such as technical staff, and other important positions.

Financial capability: This investigates the current financial situation of a contractor and assesses the stability of their finances so the contractor is unlikely to have any issues while executing the project linked to financial insufficiency. This may be done using a variety of metrics, such as the current ratio, financial reference from banks, good credit rating, assets ownership, and balance sheets.

Health and safety: The contractor's behavior toward the project's health, safety, and environmental considerations can be characterized by the safety guidelines. This is

further reflective of the availability of necessary employees and policies, in addition to the history of incidents that have occurred in the past.

Equipment capability: The competency of the equipment is reflected in the availability of tools and machinery. In addition, the sufficiency and appropriateness of that apparatus fall under the scope of this category.

Quality: This determines whether or not the contractor is competent enough to provide a result of sufficient quality. Here, a number of different aspects, such as how the contractor monitors and controls the quality as well as associated mechanisms and rules, are examined. Clients can also benefit from using certain endorsements, such as ISO certification, from measuring this characteristic.

Current workload: This criterion highlights the currently ongoing tasks that are being undertaken by the contractors prior to commencing the specific project. It is possible to determine whether or not a contractor is able to carry out the following project by looking at the contractor's net worth as well as its present assets and ability to bid.

Furthermore, (Khoso & Yusof, 2020) also came up with the following table (table 2.1) that states the criteria and sub-criteria that received considerable number of citations in the articles and many authors consider. The sub-criteria are listed in a descending order, the first sub-criteria are the top ranked in its category.

Table 2.2: Contractor selection criteria and sub-criteria and their ranking (Khoso & Yusof, 2020)

Category	**sub-criteria**
Experience and Past Performance	No. of years in construction Past failures in completed projects Experience in similar projects Claims and litigation history Size, location and number of similar projects Quality in past completed projects Projects completed on schedule Projects completed on budget Client satisfaction Awards No. of projects in hand History of change orders
Personnel Capability	Experience of technical personnel No. of technical staff Qualification of key staff Staff training
Financial Soundness	Turn over Credit training Financial references Financial firmness Financial statement Owned financial funds Working capital Obligations Liquidity Profit Bonding capacity Net worth Balance sheet Current ratio Financial audited report Current assets
Safety	Safety record HSE policy/environmental policy Safety performance
Equipment Capability	Equipment availability Insurance policy Equipment condition Equipment owned by contractor
Management Capabilities	Qualification/experience of managerial staff Project manager qualification and experience Project management system Financial management Monitoring and controlling procedure Management knowledge Senior management Availability of managerial staff

	Resource management Management structure Subcontracting management Site organization policies
Quality	Quality control policy Compliance with quality and standard Quality management system ISO certification
Relationships	Past client relationships Subcontractor relationship Relationship with supplier Relationship with consultants Relationship with insurance companies
Geographic Familiarity	Experience in local area Local subcontractor hiring Familiarity in local labor, supplier, weather, and authority Understanding of local politics
Other	Political factor Risk sharing Flexibility in design changes Size of firm Cost overruns Time overruns Subcontractor training Chances of bankruptcy Design services capacity Ability to control time and cost Expected risk IT knowledge

2.7 Selection Criteria in Road Construction Projects

Contractor selection has been a topic that raised many questions, and many articles have been published proposing new methods and discussing selection criteria. This was to solve the lowest-price award criteria, and evaluation which is criticized since many problems are associated with this selection procedure, such as cost overrun or project termination due to insufficiency of the contractor. During the pre-tender phase, it is worth mentioning that the client has limited knowledge about the technical aspects and selection procedure as a whole. Sophisticated selection methods might end up having opposite outcomes. As well as, clients do not know which selection criteria to

choose to evaluate the contractors since there is a large number of criteria, and some criteria mentioned in most papers are either hard to evaluate, or data is challenging to obtain. Furthermore, having more criteria in the selection procedure to evaluate will result in spending more time and cost. According to (Lambropoulos, 2007), more criteria to evaluate can complicate the selection and evaluation process and might encourage more subjectivity in evaluation. Another issue is that a very limited number of articles discuss criteria for a specific kind of project, and the majority of the published articles discuss criteria as general for all kinds of projects, which conflicts with the construction management principle that states that every project is unique. Since the selection criteria is a major gap in the selection of the contractor, the author of this thesis went through articles that discussed criteria in relevance to a road construction project which is part of the topic of this thesis. Table 2.2 shows the number of articles that mentioned criteria in road construction projects.

Table 2.3: Most cited criteria in road construction-related articles

Author	**Selection Criteria**
(Oad et al., 2021)	1. Company experience 2. Innovation 3. Performance 4. Management skills 5. Resources 6. Management system 7. Project cost
(A. H. Elyamany et al., 2012)	1. Bid price 2. Quality of past contractor performance
(El-Abbasy et al., 2013)	1. Project main requirements 2. Financial capability 3. Past performance
(Abdelrahman, Asce, et al., 2008)	1. Bid price 2. Contract time 3. Warranty 4. Unauthorized time 5. Rejected claims 6. Quality 7. Lane rental cost

	8. Traffic control 9. Employees
(Abdelrahman, Zayed, Hietpas, et al., 2008)	1. Bid price 2. Contract time 3. Unauthorized time 4. Rejected claims 5. Quality 6. Lane rental cost 7. Traffic control
(San Cristóbal, 2012)	1. Safety rating 2. Reference from previous projects 3. Cost 4. Completion time 5. Technical capability 6. Management capability 7. Experience 8. Financial status
(Lambropoulos, 2007)	1. Cost 2. Time
(A. Elyamany et al., 2010)	1. Quality Control
(Hasnain et al., 2018)	1. Cost 2. Performance 3. Project control 4. Quality control 5. Health and safety

Table 2.2 shows the articles which talk about criteria in regard to road construction projects that were discussed by (Araújo et al., 2019). This actually discusses the gaps that were found by (Khoso & Yusof, 2020) in regards with:

1. General criteria for all projects
2. Criteria with data hard to access
3. High number of criteria
4. No definite definition or scale to evaluate these criteria

Furthermore, (Khoso & Yusof, 2020) made a thorough review of this topic by considering 500 articles that were published between the years 2000-2018. Then they

did a screening for these 500 articles and ended up by reviewing 71 highly cited articles in relevance to this topic, and they came up with a conclusion about methodologies and criteria relevant to contractor selection in the construction industry. Table 2.3 shows the number of articles published mentioning criteria in different types of projects that emphasize the problem and research gap discussed earlier in table 2.2.

Table 2.4: Articles published in various construction works (Khoso & Yusof, 2020)

Project type	**Number of publications**	**Percent of contribution**
General projects	66	93
Road projects	3	4.20
Hydro projects	1	1.40
Industrial projects	1	1.40

2.8 Summary

A brief explanation about tendering has been introduced in the beginning of this chapter. The history of contractor evaluation in terms of evaluation method and criteria has been covered in this chapter. For evaluation criteria, eight selection methods have been discussed in which both points of strength and weaknesses have been discussed. In the last part, the history of selection criteria is discussed by looking back at criteria used and mentioned in past studies. The next chapter will provide an in-depth explanation of the selected evaluation methods and the criteria used to evaluate the contractors.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

Regularly, we are tasked with making a variety of decisions. To successfully complete the selection process, it is necessary for us to determine the desired goal and choose one of the available options that correspond most closely to the circumstances. In most cases, the execution of a project will necessitate that all of the participants conform to a particular procedure in order to arrive at absolutely clear judgments. There have been many different strategies produced throughout the course of time in order to address issues pertaining to decision-making. These strategies have been enhanced and altered in order to accommodate the issues that have become more advanced. The process of making decisions was made easier by the development and implementation of a wide variety of strategies in a variety of sectors, including business, science, and technology, amongst others. Methods such as the AHP, TOPSIS , Fuzzy models, and Hybrid models are examples of some of these techniques. This chapter will explain the methodology that was adapted for research and a detailed explanation of the proposed system by the author.

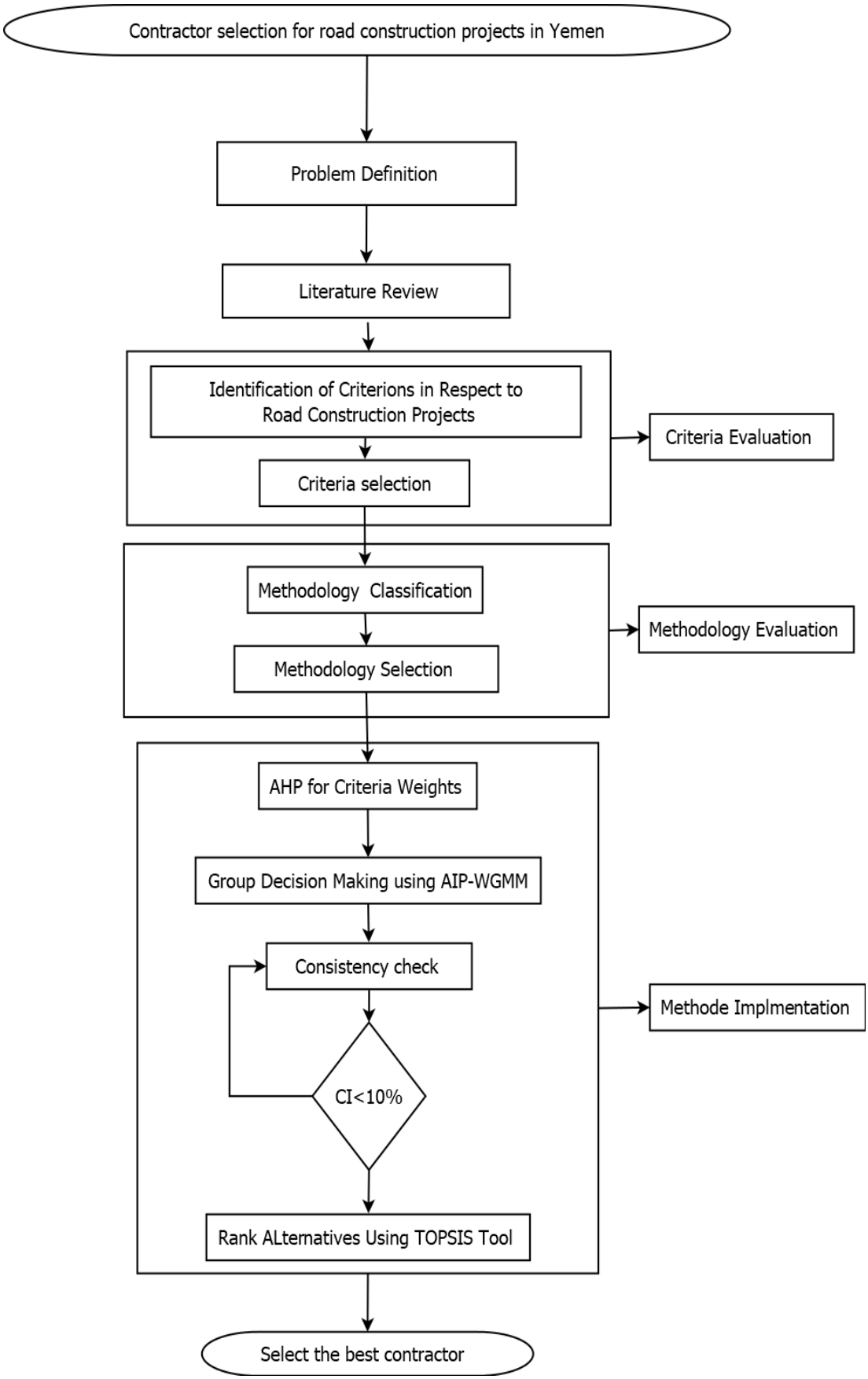

Figure 3.1: Flowchart of the study

This research study will conform to the methodology framework that is depicted in the diagram that can be seen above, which is referred to as Figure 3.1.

3.2 Problem Definition

The selection of a suitable contractor represents a significant challenge for engineering projects. If the contractor chosen is not adequately qualified for the task at hand, this might result in a number of complications for the project that is currently being executed. The method of selecting a contractor that is most frequently employed is the practice of awarding the contract to the bidder who submitted the lowest price without taking into consideration other factors such as quality, previous experience, safety, etc., which can lead to complications such as cost overruns and schedule delays. The present technique of selection has a number of drawbacks, one of which is that it frequently depends on the knowledge and experience of the one making the decision, despite the fact that these qualities vary from person to person. No standards have been developed to ensure the selection process, and no solid method has been developed that can be easily used without needing the presence of an expert. However, some selection tools and criterions that have been introduced in the literature review in different articles encourage subjectivity which the author of this thesis is trying to avoid since it acts as a cancer for the selection procedure and acts as a black hole that leaves a gap for corruption in the selection in Yemen which was criticized by the OECD. The road construction industry in Yemen is an active sector since it is a third-world country. It is still in need of many infrastructures development the lowest price award is not doing any favor for this sector given the number of litigations between the public sector, contractors, and the number of unfinished projects, and projects that countered cost over-run and schedule delays. However, the selection of the lowest price contractor is desirable by officials in the public sector because it is easier to

justify their selection to the taxpayers. Another major reason that encouraged the writer to do this research is that according to (Khoso & Yusof, 2020) contractor selection problem in different countries, depending on the origin of the author in respect to Yemen, is zero, and there have been no attempts to enhance the contractor selection in Yemen which is the origin of this thesis author.

3.3 Literature Review

When choosing a professional executor, the most crucial element to examine is whether or not he has distinguishing qualities. If the wrong option is chosen, it could cause problems between the client and the contractor and cause the project to fail. On the other hand, the great majority of past studies agree that selecting contractors only on the basis of price is ineffective for selecting the best competent contractors capable of completing projects financially and with positive outcomes(Wardani et al., 2006). The problem associated with the selection criteria that the contractor will be evaluated in respect to will be discussed further in the following paragraphs, and these problems were defined with respect to the literature review that the author carried out to write this thesis.

1. General criteria

Most of the published articles in the past two decades talk about general criteria that can be used to select a contractor for any type of project, and only very few articles that talk about specific criteria for a specific type of project that are mentioned earlier in table 2.2 and 2.3 Construction industry is very wide varying from infrastructure, roads/highways, power plants...etc. And not having pre-specified evaluation criteria for contractor selection is not practical and may increase risk during the selection procedure(Khoso & Yusof, 2020).

2. High number of criteria

One of the problems associated to selection criteria in contractor selection is a number of criteria. In particular, a significant portion of selection criteria only infrequently receives the attention of researchers. It is important to have a conversation about the many inconsistencies that exist between the categorization concerns of contractors and their selection criteria. Having a large number of criteria to assess could result in more time and more resources wasted during the evaluation phase(Khoso & Yusof, 2020).

3. Criteria with challengeable data to obtain

Non-price criteria, those mentioned in some articles, such as familiarity with local politics, history of claims, past failures, quality in previous projects, familiarity with local suppliers...etc., are not easily measured and evaluated accurately due to the fact that this kind of information is difficult to obtain from the contractor's side and it might result in confusion during evaluation since there is no specified scale; and therefore, it is of the most importance to determine criteria within which the appropriate data may be readily collected and evaluated (Skitmore, 2002).

4. Criteria with no specific scale

Some non-price criteria such as quality, health and safety, and equipment capability are not easy to evaluate since it does not have a specific scale to refer to in order to provide a score. There has never been a definite scale for assessing the non-price criteria. This might encourage subjective judgments; for instance, safety is based on non-price criteria that do not have a specific scale and cannot be easily evaluated; thus, this might lead to confusion while scoring the contractors. According to (Waara & Bröchner, 2006), there has never been a specific scale for non-price criteria such as quality, equipment, and health and safety.

Various scholars believe that the evaluation and selection phases of a tender are critical. As a result, the impact of all of these threats will be reduced or maximized (Chiang et al., 2017; Darvish et al., 2009). On the contrary, the formulation of the selection problem includes a number of criteria, and clients must choose between competing goals and limited resources. The previous study has shown that a considerable majority of construction project failures may be linked back to a lack of effective tools for properly evaluating contractors prior to contract awarding (Kashiwagi & Byfield, 2002). However, some methodologies were criticized for various reasons. For instance, according to (Semaan & Salem, 2017), it's difficult to use AHP to evaluate additional variables in projects, especially if they're interdependent. (Jato-Espino et al., 2014) stated that analytical network process (ANP) is harder and requires more time since it has fewer steps than AHP. Fuzzy models have far more applications and publications since they allow a more flexible scoring system by providing ranges between definite score values offered in some methodologies, but they encourage subjectivity which that leads to certainty. (Liu et al., 2016) expressed concern about the shortcomings of contractor selection methods based on fuzzy logic; for example, expert's opinions have a considerable role in their findings, which might lead to false results. The TOPSIS was utilized in (Taylan et al., 2018) study. After the AHP, it seems that this method is the second most often used choice in the construction industry. Because TOPSIS is a methodology that can be computed and is organized algorithmically, which significantly simplifies its implementation approach (Jato-Espino et al., 2014). The VIKOR technique, much like TOPSIS, looks for the solution that comes the nearest to the overall best. However, in contrast to TOPSIS, the VIKOR method's normalizing procedure is carried out linearly rather than vectorially (Jato-Espino et al., 2014). These methods are utilized whenever there is a requirement to

compare the criterion with a number of other options. In none of these approaches can the disproportionately low weights of certain criterion be made up for by the disproportionately high weights of a few others due to the higher weighting of those few criteria (Creuza Borges De Araújo et al., 2017).

(Aruldoss et al., 2013) and (Jato-Espino et al., 2014) Concluded that both methods PROMETHEE and ELECTRE are hard to implement due to their level of sophistication in which the first one is not easily applicable if you have a large number of criteria whereas the latter one requires a lot of time in order to be computed. Furthermore, some authors encouraged an increase in hybrid approaches, which can be defined as a using of two or more approaches by combining them for the selection of contractors as a result of the numerous problems that are associated with decision techniques, which are not so comprehensive that they can adequately deal with the issues on their own (Khoso & Yusof, 2020). The application of MCDM strategies in combination offers a number of significant benefits. After integrating the individual techniques in the appropriate manner, the specific approach may then be employed to positive effect.

3.4 Criteria Evaluation

Evaluating a contractor based on various parameters opens the door for fair and strong competition among contractors. It also contributes to awarding the contract to the best contractor taking into account the best price. The traditional award method that is still followed in some countries has created many losses in terms of money and time in many projects, and in some cases, projects were terminated, but the main concern is how to choose the appropriate criteria that help the client to evaluate the contractors.

3.4.1 Criteria Classification

However, the practice that the author followed in this thesis in regards to criteria in the selection of the contractor in the road construction projects is based on intensive literature review in a way that they do not conflict with the problem stated in regards to evaluation criteria that are mentioned earlier in this chapter. Based on the three most-cited criteria in road construction projects (Financial, Experience, and time) the author referred to (Khoso & Yusof, 2020) article, which did a thorough research of 71 highly cited criteria which and did conclude the criteria category with their related sub-criteria with ranking which is showed in table 3.1.

- General Criteria is represented by the notation **G**
- Criteria with challengeable data to obtain is represented by the notation **CD**
- Criteria with no specific scale are represented by the notation **NS**
- Criteria considered are represented by the notation **C**

Table 3.5: Criteria classification in respect to Yemen road construction projects

Category	**Related sub-criteria**	**Response**	**Note**
Financial soundness	Turnover	CD	Firms prefer not to disclose this data in order to avoid high tax rates, so this may be associated with the inaccuracy of data
	Credit rating	CD	No credit transactions in Yemen banks
	Financial reference/banking links	G	It cannot be used to show financial ability. Banks in Yemen do not provide these anymore due to the number of increased litigations.
	Financial Firmness	G	No details on how to assess it and no details provided
	Financial statement	G/NS	This is too general because financial statements involve different parameters
	Owned financial funds	CD	Data is hard to obtain since it needs accumulated profits re-invested
	Working capital	CD	Similar to the current ratio, but which current ratio is preferred since it is a ratio
	Obligations	CD	Hard data to obtain in means of the accuracy of data since firms tend to keep this data private
	Liquidity	CD	It cannot be easily evaluated because and in order to calculate the liquidity of a company an expert is needed

	Profit	CD	Firms prefer to disclose this due to tax issues. Sometimes false data
	Bonding capacity	CD	Requires a lot of data that is not easily accessible
	Net worth	CD	Firms prefer not to disclose this data due to tax issues, and the data is challenging to obtain
	Balance sheet	CD	Requires specific time horizon and too much data that is hard to access
	Current ratio	C	Considered
	Financial audited report	CD/NS	Data is not easily accessible, and no specific scale to refer to
	Current assets	CD	The current ratio is considered which involves current assets
Experience & Past performance	Number of years in construction	C	Considered since easily accessible and important parameter
	Past failures in completed projects	CD	Challenging data in means of accuracy because firms hide this type of data
	Experience in similar projects	C	Considered
	Claims and litigations history	CD	Not easily accessible data
	Number and location of similar projects	G	Experience in similar projects is more precise
	Quality in past completed projects	NS	No scale to refer to
	Projects completed on schedule	C	Considered
	Projects completed on budget	C	Considered
	Client satisfaction	CD/NS	Challenging data to obtain and no scale to refer to
	Awards	NS	Not applicable in Yemen, and no scale to refer to
	Number of projects in hand	C	Considered
	History of change orders	CD/NS	Challenging data to obtain and no scale to refer to

It is clear from looking at table 3.1 that "Time" criteria are not taken into account. This is due to the fact that one of the solutions to the problems with the criteria is to include in the contract clause non-price criteria that are difficult to evaluate, and "Time" criteria are one of the parameters that fall under this category.

3.4.1.1 Criteria with Respect to Road Construction Projects

As mentioned earlier in this chapter and in chapter 2, only very few articles discussed contractor selecting criteria when it comes to road construction projects; Table 2.3 shows that the percentage of contribution of these articles in respect to the overall is 4.2 %. Furthermore, it was observed according to table 2.1 in chapter 2 that among the published articles that has discussed the criteria for road construction projects, the three most cited criteria are Financial, Experience, and Time. Furthermore, this was emphasized by (Araújo et al., 2019), that conducted research about criteria for different types of projects and the most-cited criteria in respect to different criteria that are shown in table 3.2.

However, it is worth mentioning that these articles did not state a way to conduct the evaluation of these criteria, nor it specified a scale that acts as a reference to evaluate them.

Table 3.6: Categories of most cited criteria (Araújo et al., 2019)

Type of Project	**Categories of most cited criteria**
Channel	1.Financial 2.Company management 3.Health and safety/enviroment
Bridge	1.Quality 2.Time 3.Staff features
Green construction	1.Financial 2.Company management 3.Technical/technology
Refurbishment	1. Financial 2.Staff features 3.Experience
Hydroelectric	1. Financial 2.Quality 3.Flexibility and responsivness
Highway	1.Financial 2.Experience 3.Time
Building	1.Financial 2.Quality 3.Staff features 4.Time
In general	1.Quality 2.Staff features 3.Financial

3.4.2 Criteria Selection

The selection was based on the literature review done previously in which the three most-cited criteria were considered according to (Araújo et al., 2019) and (Khoso & Yusof, 2020) the most-cited criteria with respect to highway/road construction projects that were mentioned in the published articles which were also mentioned in table 2.1 and 2.2 in chapter 2 are as follows:

1. Financial
2. Experience
3. Time.

Then sub-criteria from (Khoso & Yusof, 2020) were examined and chosen depending on phone interviews with officials in the department of transportation in Yemen.

3.4.3 Selected Criteria

1- Bid price: It is the price offered by the contractor in return for executing the work. It is represented by a bill of quantities which are provided by the client; the client, when issuing the tender documents, provides a table of quantities of the work, whether it is measured by quantity or by meters, and the contractor has to fill these forms and tables in order to get the price. However, the price of the project is estimated, and the bid price submitted by the contractor is compared to the estimated bid price. In case of abnormality of the submitted bid price where the deviation between the submitted and estimated price is huge, the contractor will be asked for justification and, in most cases, disqualified. This parameter is price criteria and does not require any kind of conversion or evaluation; it can be directly put into TOPSIS tool in a numerical manner for ranking purposes.

2- Current ratio: This parameter gives the client an idea about the financial capability of the contractor and answers the question of is this contractor financially capable of executing this work. Work capital and current ratio are similar, but in terms of confidentiality since it does not disclose any sensitive data because the normal practice in most parts of the world is that companies tend to keep their financial data confidential to avoid paying high taxes. The current ratio is easily measured, and it gives a full idea on how the firm is doing. The higher the ratio, the better. Current Ratio= Current assets/Current liabilities. The ratio can be used directly and put straight into the TOPSIS tool in a numerical manner for ranking purposes.

3- The number of years in construction: This parameter falls under experience criteria in which it gives the client an idea about how many have this particular contractor been doing construction work in general. It does not specifically say experience in the road construction field, but it measures the number of years in construction field in general. This parameter is expressed in years, and it can be directly be put into the TOPSIS tool for ranking purposes.

4- Experience in similar projects: A bidder should have expertise in the execution of a project that is comparable in nature to the one that has been described in the scope of work if they are submitting an offer for the job. So, he has to submit road construction projects he has done in the past since this system deals with selecting contractors for road construction projects. Expressed in numbers of years.

5- Projects completed on schedule: This again falls under the experience parameter, which gives a better idea of the contractor's commitment in terms of time to previous projects. Finishing projects on time depicts that the contractor has the financial ability, workmanship, equipment, and resources to finish the project on time, and he is professional. However, this requires the contractor to submit completion reports for past projects in order to evaluate and then put them into the system by the number of projects. They are expressed by the number of projects.

6- Projects completed on budget: This again falls under the experience parameter, which gives a better idea of the contractor's commitment in terms of budget to previous projects. Finishing projects within budget depicts that the contractor has the financial ability, workmanship, equipment, and resources to finish the project on time, and he is professional. However, this requires the contractor to submit completion reports for past projects in order to evaluate and then put them into the system by the number of projects. Expressed by the number of projects.

7- The number of projects on hand: In other words, this means the current workload of a contractor while he is submitting to the tender. This is crucial since it determines whether the contractor's resources and capabilities are sufficient enough to undertake the project in the presence of other projects at the same time. However, the lower workload, the better, and it can be inserted into TOPSIS tool as a number of projects.

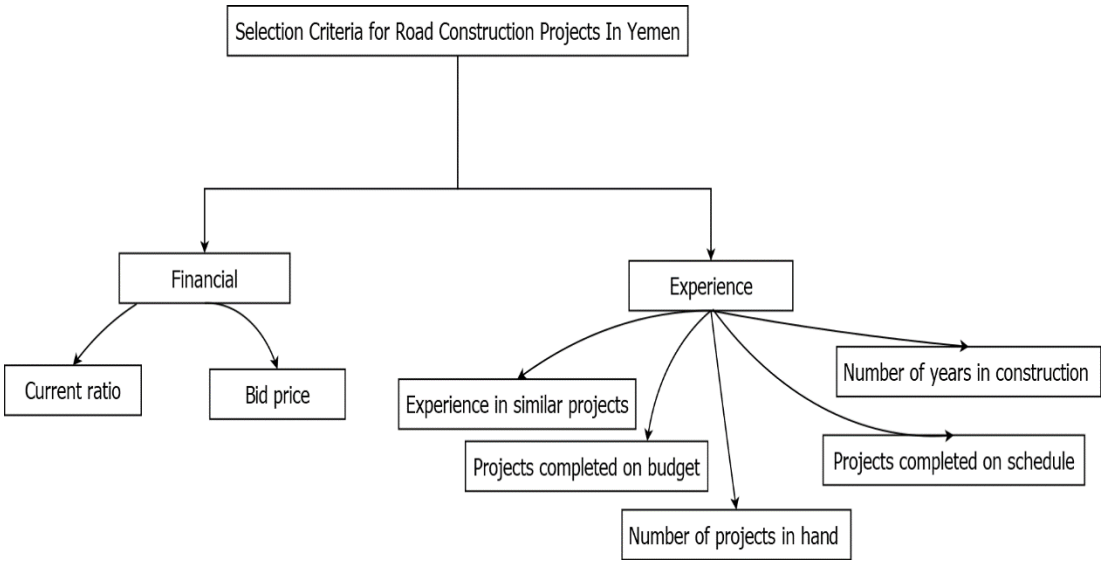

Figure 3.2: Criteria selection for road construction projects in Yemen

3.4.3.1 Non-Price Criteria to be Stated in Contract Clause

Some non-price criteria do not have a specific scale to refer to in terms of scaling and encourage subjectivity. This has been a research gap for a long time and has not been filled; it was mentioned in the best paper in 2006 published in the journal of construction engineering and management (Waara & Bröchner, 2006). It says that it has never been a scale for definite scale for some non-price criteria. It is suggested by the thesis author is in order to fill this gap, these non-price criteria should be stated in the contract clause, and the contractor have to follow these stated in the contract. The criteria mentioned here are general and are vital for every project in every field, yet they are not measurable. Luckily this is the current practice in Yemen according to the executive tender and purchase law that was issued back in 2007 by the Yemeni government at that time and approved by the president.

These parameters are the following:

1- Quality

2- Equipment

3- Technical staff experience and number

4- Project duration

5- Health and safety measures

3.5 Method Evaluation

MCDM is a good approach to making decisions in areas where choosing the best option is hard. The main goal is to find different applications and ways to use them and to suggest ways to use them that are the most reliable and effective. This will help find the best alternative. Using multi-criteria to make a decision has been used in many areas. MCDM helps choose the best criteria when there are many criteria. The best one can be found by analyzing the different scopes and weights of the criteria and then choosing the best ones using any MCDM techniques.

3.5.1 Method Classification

Some of the selection methods that were mentioned previously were criticized for the following reasons:

Dimensional weighting method (DWM): is based on the arbitrary and subjective judgments of those who make choices. Second, you can make up the difference if you have a strong score in one category but a low score in a different category. Third, the concerns about the inconsistency of data given by contractors given by contractors are not taken into account. Fourth, the issues that result from having a wide range of decision-makers viewpoints are ignored. Finally, accommodating several criteria, each of which uses a different unit of measurement, is impossible.

MAUT: This strategy imposes a huge load on individuals in charge of making choices as it demands them to answer a big number of hypothetical questions in the form of a random in order to learn about their real preferences. This is a major drawback of the

approach. It is also required to supply accurate probabilities in order for the utility function to be produced. Another problem with MAUT is that it might take a long time to make judgments when many distinct elements need to be considered. Also, the essential needs of this theory imply rationality, which includes criteria compensation. This rationale also demands the technique for aggregation of all criteria in order to produce a utility function synthesis based on many criteria. The individual making the decision does not always take this logic into account. Finally, due to a lack of capabilities, MAUT is unable to deal with several decision-makers at once.

AHP: As pointed out by (Mahdi et al., 2002) for AHP to be viable, the process must be able to work with matrices that are identical in mathematical form—specifically, a positive reciprocal matrix—in order to work. Lastly, AHP is not the optimal technique for evaluating major factors in the construction project, particularly when they do not depend on each other (Semaan & Salem, 2017).

Group decision in AHP: The arithmetic mean is the method of aggregation that is used most often, but various methods have been presented in the scientific literature. The unanimity criterion, often known as the Pareto principle, is fulfilled by both this arithmetic mean and this geometric mean; however, only the geometric mean meets the homogeneity condition and the reciprocal property(Escobar & Moreno-Jiménez, 2007).

TOPSIS: (Khoso & Yusof, 2020) Found through their intensive research among highly cited criteria that TOPSIS was mentioned the most, which makes it a strong method for comparing alternatives. However, one major issue is that TOPSIS needs weights

of criteria and defined criteria in order to be an effective tool which is why AHP is combined with TOPSIS in this research.

Fuzzy AHP: According to (Hosny et al., 2013; Jaskowski et al., 2010), It takes a lot of time and effort to understand the mathematical and probabilistic models that go into fuzzy AHP. Using a fuzzy analytical hierarchy technique when the criteria are well-defined and well-established may have a negative influence since it causes confusion when rating alternatives. According to (Liu et al., 2016), It is argued that fuzzy models of contractor selection have a range of limitations; for instance, this significantly relies on the opinion of experts, which could lead to biased findings.

PROMETHEE: Using PROMETHEE procedures necessitates a significant variance in the criteria of each evaluation. Discordance cannot be taken into account while constructing PROMETHEE outrank relations. By adding or deleting an action, the relative position in the preorder between two actions may be adjusted. Adding or eliminating an action that is overshadowed by the others(De Keyser & Peeters, 1996). It is not easy to use (Jato-Espino et al., 2014).

ELECTRE: One major drawback of this method, as (Sabaei et al., 2015) claimed, is: The disadvantage of ELECTRE's regular ranking is that it requires the inclusion of an additional threshold. Furthermore, the ranking of the alternative is reliant on the size of this threshold, for which there is no "correct" value. According to (Aruldoss et al., 2013), ELECTRE methods are time-consuming.

Hybrid models: Hybrid models received a good review, but there is a number of criticisms by (Khoso & Yusof, 2020), who claim that some hybrid models are way

complicated to implement. They also stated that hybrid models are becoming more popular because traditional decision-making methods are not sufficiently comprehensive to deal with all the problems independently.

3.5.2 Method Selection

Based on literature review and the popularity in means number of publications, applications, and review these methods have had, AHP and TOPSIS both methods were selected among others for the following reasons:

3.5.2.1 AHP

To deal with the complicated decision problems of today, In order to take into account all of the relevant aspects, you will need to adopt a new attitud that affect how well you reach your goals and how consistent your decisions are so you can get important results. Also, the logic should be acceptable, make sense, and not be too hard to understand so that it can be used by everyone, not just experts and smart people. Initial studies have shown that the AHP method is the best way to solve complex problems (Al-Harbi, 2001). Using a hierarchal analysis system helps solve complicated problems by using a structure made up of relevant parameters and outputs in a hierarchical way. This structure uses the decisions to set priorities and make predictions about what could happen based on the decisions. The results are used to rank the options, divide up the resources, compare utilities and budgets, and practice managing the system by figuring out how sensitive the results are to changes in the decisions and for planning for the future. The AHP gives you the structure you need to solve many different kinds of problems. It also helps you make good decisions in hard situations by making them easier to understand and encouraging you to make decisions that make sense.

However, AHP heavily relies on the judgment of the decision-makers using saaty's (1-9) scale in figure 3.3, which in long decision problems might end up having too many matrices and time-consuming in addition to that, the decision might start to be more inconsistent since the decision-maker has to us the scale to compare a considerable number of factors. As (Hafizah Mohamed et al., 2017) publication that stated, each participant must evaluate 255 items totaling 153 criteria with criteria and 102 criteria with alternatives by completing the pairwise comparison form based on criteria, sub-criteria, sub-criteria, and alternatives with evaluation scores.. Thus, in the proposed system in this thesis by the author, AHP is used for weighting purposes which is best known according to (Khoso & Yusof, 2020). Furthermore, according to (Ossadnik et al., 2016), the AHP has a better understanding of the situation as a whole. Its hierarchical structure is easier for new users to understand, and its simplicity makes it better for showing and judging group aggregation techniques. The AHP articles have now been analyzed to complete the research gap in the suggestion of a method for the implementation of group decision-making in relatively small groups, which was discovered in the first place. Lastly, according to (Khoso & Yusof, 2020), AHP is the most used approach owing to its simplicity of application and comprehension.

From the abovementioned paragraph, the following can be concluded:

1- AHP is the most used approach owing to its simplicity of application and comprehension
2- AHP has a better understanding of the situation as a whole
3- AHP is not the optimal technique for evaluating more criteria
4- Due to its simple function, AHP is mostly used for weighting reasons in literature

5- AHP is the second most employed technique in the construction industry

3.5.2.1.1 Group Decision-making in AHP (AIP-WGMM)

When people are willing to or are required to acknowledge their personal preferences (values, aims) for the sake of the organization, they operate in harmony with one another and pool their judgments in such a way that the group becomes a new 'individual and behaves like one. The accumulation of everyone's opinions creates a cumulative effect that is beneficial. At each successive level of the aggregation process, individual identities are obliterated. We are not concerned with the priorities of individual members. As a consequence of this, there is no synthesis for any one particular person, and the Pareto principle is invalid. Because the members of the group start to act as if they are a new "person," it is necessary to ensure that the reciprocity criterion for the judgments is met, which will be discussed further in chapter 3 . As a result, the geometric mean should be utilized for the reasons that have been presented(Forman & Penman, 1996). The AIP-WGMM is chosen to be the group decision technique for this thesis due to several reasons:

1- AIP has been accepted and tested for different scenarios

2- It corresponds to pareto social optimality and other social axioms

3- Does not violate the reciprocal property

4- Easy to implement

5- It can be implemented for a larger group (more than five members)

3.5.2.2 TOPSIS

To measure the distance from both positive and negative ideal solutions, TOPSIS, which is a method that belongs to the family of the MCDM, is frequently used as a methodology for potential ranking solutions. This technique has been utilized in the past, both on its own and in hybrid models. In comparison to other methods for

determining distance, such as VIKOR, TOPSIS was the one that received the most citations, which makes it a more flexible method for evaluating potential alternatives (Khoso & Yusof, 2020). After the AHP, it seems that this method is the second most often used choice in the building industry. As a result of the fact that TOPSIS is a technique that can be computed and its algorithmic framework substantially simplifies its implementation process (Jato-Espino et al., 2014). It has excellent computing efficiency, and the procedure is not complicated in any way. One more of its many advantages is that it may provide a straightforward mathematical representation of the relative performance of the various alternatives. In addition to this, the TOPSIS technique allows for a significant deal of flexibility when defining the options set. The approach is able to choose the optimal option in a short amount of time, and it is simple to add to, delete from, and enlarge the TOPSIS matrix. Finally, in this system, faults may be checked for. Similar methods are introduced, such as VIKOR, but TOPSIS is the most widely known and easily implemented, and it is the most cited MCDM tool. This is due to the fact that it is a strong tool for ranking alternatives (Khoso & Yusof, 2020). So, what can be concluded is that the reason for choosing TOPSIS are:

1- Second most employed technique after AHP
2- TOPSIS is a computationally accessible and algorithmically organized approach that significantly streamlines its implementation process
3- From the category of distance method (TOPSIS, PROMETHE, ELECTRE, VIKOR), TOPSIS received a considerable number of citations, making it a more flexible way for evaluating the options
4- TOPSIS received very low criticism compared to other methods
5- Easily implemented

3.6 Method Implementation

The proposed method is a hybrid model that combines both AHP and TOPSIS for the evaluation and selection of contractors in road construction projects in Yemen. In addition, the AIP-WGMM was considered for the group decision-making part in AHP since such decisions are made through a board of members; AIP combines their priorities with taking into consideration the consistency of their decision, whereas WGMM is a mathematical approach to analyze these priorities with respect to AHP reciprocity manner and the social axioms. AHP will be used to weight the criteria defined for road construction projects through literature review and interview, and TOPSIS will use the weights obtained through AHP to rank the contractors based on the same criteria that were weighted in AHP. Senior officials (Tender board members) are supposed to rank their preferences using the 1-9 saaty's scale in order to obtain the criteria weightage, but this was not done due to the fact that it is hard to communicate with these people; they tend not to get involved in any activity due to political crisis going on. Thus, the author was able to get the following weightage from engineers that were involved in tendering. However, the methodology shall be implemented in the stated matter through AHP for weightage, AIP-WGMM for group decision matrix then lastly through TOPSIS to obtain the ranks. As it is illustrated in the following figure, phase which is the first stage where project definition is done, documents preparation and other stuff is done, the parameters defined earlier for road construction projects shall be used, non-price parameters shall be included in the contract clause as project requirements and the weightage shall be obtained using AHP, after that in phase 2 the data submitted is reviewed and TOPSIS is utilized, weights acquired through AHP are inserted into TOPSIS, finally after getting the results from TOPSIS the alternative with the closest number to 1 is considered as the best alternative.

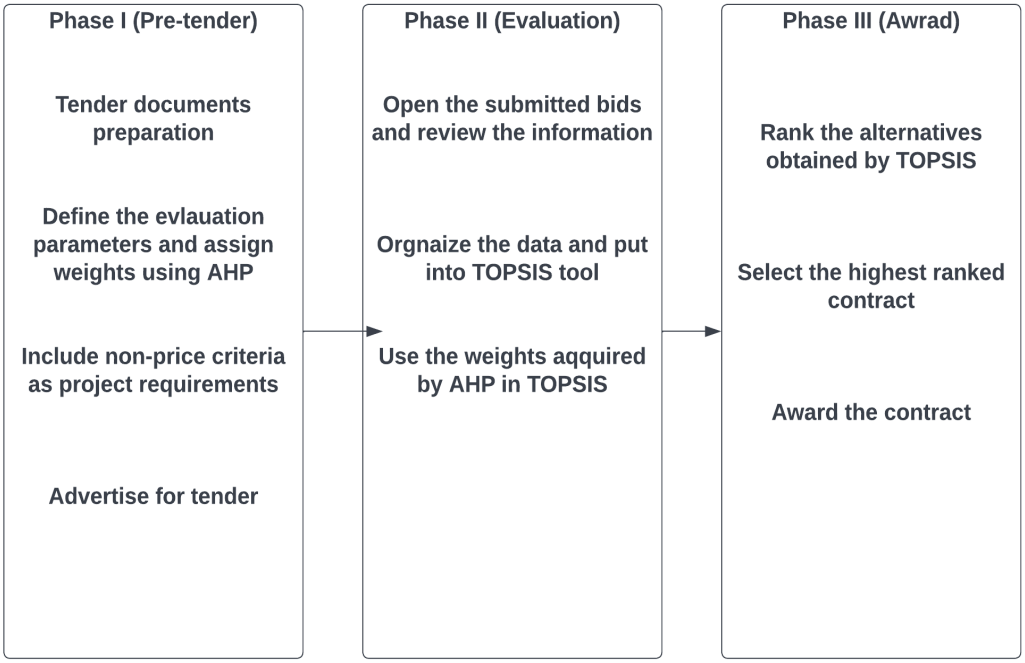

Figure 3.3: The skeleton of the tendering process

3.6.1 AHP

The following criteria weights were obtained through engineers in the Transportation and Highway department in Yemen due to the difficulty of getting these weights through AHP. In normal practice, when this method is implemented, AHP shall be used for this purpose.

Table 3.7: Criteria weights for this research

Criteria	**Weight %**
Bid price	70
Current ratio	5
No. of years in construction	5
Experience	5
Projects completed on schedule	5
Projects completed on budget	5
Current workload	5

Nevertheless, according to (Al-Harbi, 2001) and other researchers, the following steps should be implemented to use AHP:

Step1: Explain clearly the problem at hand and identify its desired outcome

Step2: Establish a decision matrix based on pairwise comparisons (A). During this stage, set up the hierarchy from the highest level, which is the overall goal, down to the lowest level, which is the attribute or sub-attribute that the next level depends on. C1, C2... Cn represents the elements, whereas aij is a numeric ranking. Using the standard scale of measurement shown in figure 3.3, the two things are ranked by how important they are.The preference between the two elements is shown in the following matrix:

$$A = [a_{ij}]_{n\times n} = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \end{array}$$

Step3: After making the matrix, the next job is to determine a vector of priorities or weightings for each element inside the matrix. The decision matrix needs to be normalized, and the priorities of this matrix need to be found. First, all the calculations for the priority vectors in the comparison matrix need to be normalized. In this stage, you have to add up each column on its own. Then, each value is divided by the total value of the column it is in. The final step is to find the average rows and the relative weights

Strep4: Following the determination of the priority vectors, the consistency ratio of the estimated vector must be calculated. Because decision maker's judgments are often inconsistent, the AHP approach includes management irregularities into the model and offers a measure of these inconsistencies to the decision-maker. According to (R. W. Saaty, 1987), the practical top limit is 10%

3.6.1.1 Consistency Check

The consistency ratio is calculated using the procedures below:

a. Carry out the consistency checks by calculating the weighted sum matrix. Finding the weighted sum matrix is accomplished by multiplying the priority vector by the column to which it corresponds and dividing the values obtained by their priority vector to find *Tmax*

b. Measure pairwise inconsistencies using the consistency index (CI). This is computed as follows:

$$CI = \frac{(\tau max - n)}{(n-1)}$$

Where n represents the size of the matrix

c. Finally, the consistency ratio of the judgment is derived by dividing the consistency index produced in the previous step by the appropriate number in figure 3.4 (Random consistency). Generally, the decisions are consistent and acceptable if the consistency ratio is lower than 10 percent

$$CR = \frac{CI}{RI}$$

d. In case it is more, we need to analyze and reconsider our decisions because of the inconsistency of the judgment matrix

Numerical rating	*Verbal judgment of preferences*
9	Extremely preferred
8	Very strong to extremely
7	Very strong to preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally moderately
1	Equally preferred

Figure 3.4: Saaty's 1-9 ccale AHP

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.79

Figure 3.5: Random consistency values AHP

3.6.1.2 AIP-WGMM

The application of AHP in the system that is being proposed primarily serves the aim of introducing flexibility into the system and resolving a problem that is related to the problem of weighing the assessment criteria of the contractor. As a result of the fact that each construction project is one of a kind and possesses its own distinct characteristics, it is hard to consider the same definite percentage of criteria for each and every project. As a result, AHP will provide the capability of adjusting this percentage based on the nature of the project, and AIP-WGMM will allow the group of decision-makers to make this decision together, regardless of whether they all have the same ranking and influence on the decision or whether they have different rankings and influences. The **AIP** procedure (Ramanathan & Ganesh, 1994) is based on the aggregate of the individual priorities that were determined by the pr. To determine the synthesized group priorities P (Ai) for an alternative Ai, one may do the following:

$$Pg^{WGMM}(Aj) = \Pi_{r=1}^{R}(Pi(Aj))^{w^i}$$

Pg (Aj) refers to group priority of alternative

Pi (Aj) refers to the individual priority of alternative

Wi is the group member weight

Aj is the alternative

3.6.2 TOPSIS

(Tsai et al., 2008; Wu & Yang, 2008) Explains how the TOPSIS method, which is a kind of statistical analytic technique, may be used to determine the preferred order in which assessment items should be examined. This information can be utilized to improve the quality of future assessments. The Ideal Solution is, in its most basic form, a collection of assessment items that are the very best in their respective categories. The set of assessment objects that are the worst for each characteristic is referred to as the Negative Ideal Solution, which contrasts with the Positive Ideal Solution. The selected object for assessment is the one that is most comparable to the Ideal Solution while also being the one that is most unlike to the Negative Ideal Solution. Choosing a project is a significant undertaking, and it is not always a simple process. This is because there are usually numerous ways to evaluate the impact of a project, which is especially true when more than one person is responsible for making decisions.

The TOPSIS technique is predicated on the premise that the optimum answer should be as close to the chosen option as feasible, while the non-ideal solution should be as far away as possible from the best solution. This is the core concept that underpins the method. In addition, TOPSIS operates on the premise that each Design Option has a preference to either have its impact maximized or its impact reduced. As a consequence of this, the positive-ideal solution for a criterion that wishes to be maximized is the greatest value of all the design alternatives that are taken into account, while the negative-ideal solution is the lowest value of all the design options that are taken into consideration. TOPSIS is a tool for finding the best solution from a limited number of options that meet more than one set of criteria. In the TOPSIS method's procedure system, you have to give the criteria weights and ratings of the

attributes. Most of the time, though, the TOPSIS tool's highest-ranked option is thought to be the best, and its lowest-ranked option is thought to be the worst. The following is an outline of the TOPSIS implementation steps (Jahanshahloo et al., 2006; Opricovic & Tzeng, 2004) :

1- Construct the decision matrix and determine the weight of the criteria. Let X = (xij) be a decision matrix and W=[w1,w2,w3….wn] a weight vector; criteria of the functions can be, benefit functions (the higher the number, the better) or cost functions (the lower the number, the better).

2- Determine the decision matrix's normalized value. This process converts distinct attribute dimensions into non-dimensional characteristics, allowing for cross-criteria comparisons. The scores in the evaluation matrix X must be translated to a normalized scale since different criteria are frequently assessed in different units. One of the many well-known standardized formula for normalizing values may be used:

$$nij = \frac{Xij}{\sqrt{\sum_{i=1}^{m} Xij^2}}$$

For $i = 1, \dots, m; j = 1, \dots, n.$

3- Conduct the calculations required to create the weighted normalized decision matrix. The following is the calculation that is used to determine Vij's weighted normalized value:

$$vij = wj.nij$$

$$i = 1, \dots, m;$$

$$j = 1, \dots, n.$$

4- Determine the solutions that are both positive and negative ideals. The optimal positive solution maximizes benefit criteria while minimizing criteria

associated with costs , while the ideal negative solution maximizes cost criteria while minimizing benefit criteria.

Positive ideal solution + A has the form:

$$A^{+} = (v_1^{+}, v_2^{+}, \dots, v_n^{+}) = ((\max_i v_{ij} \ |j\epsilon I), (\min_i v_{ij} \ |j\epsilon J))$$

$$A^{-} = (v_1^{-}, v_2^{-}, \dots, v_n^{-}) = ((\min_i v_{ij} \ |j\epsilon I), (\max_i v_{ij} \ |j\epsilon J))$$

Benefit criteria are represented by I, whereas cost criteria are represented by J, $i = 1, \dots, m; j = 1, \dots, n.$

5- Determine the separating distances. In order to describe the distance between each alternative and the positive ideal solution, we use the following formulas:

$$d_i^{+} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{+}\right)^2}, \qquad i = 1,2, \dots, m,$$

$$d_i^{-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{-}\right)^2}, \qquad i = 1,2, \dots, m.$$

6- Calculate how close you are to the positive ideal answer. The i-th alternative Aj's relative distance to A+ is defined as:

$$R_i = \frac{d_i^{-}}{d_i^{-} + d_i^{+}},$$

Where $0 \leq R_i \leq 1, \ i = 1,2, \dots, m.$

7- Rank the alternatives in order of preference, or choose the one that is closest to 1. The descending order of the value of Ri may now be used to rate a collection of alternatives.

3.7 Summary

The most significant research approaches used in this study are explained in this chapter. There are two sections to the chapter. The first section discusses the criteria

chosen for this study and on what bases they were selected, and the second section gave an inner insight into the tools that will be used to evaluate these criteria selected in order to choose a contractor for a road construction project. Furthermore, the application of AHP in the system that is being proposed primarily serves the aim of introducing flexibility into the system and resolving a problem that is related to the problem of weighing the assessment criteria of the contractor. As a result of the fact that each construction project is one of a kind and possesses its own distinct characteristics, it is hard to consider the same definite percentage of criteria for each and every project. As a result, AHP will provide the capability of adjusting this percentage based on the nature of the project, and AIP-WGMM will allow the group of decision-makers to make this decision together, regardless of whether they all have the same ranking and influence on the decision or whether they have different rankings and influences. These weights are later on used in TOPSIS to get the ranking of alternatives. The following chapter tests the proposed framework by implementing a case study in the Yemeni road construction sector.

Chapter 4

CASE STUDY

4.1 Introduction

Since construction makes up a considerable portion of a nation's Gross Domestic Product (GDP), and GDP is a factor that is used to measure a nation's growth, economy, well-being, etc., the process of selecting a contractor for construction projects has been a subject that has received a great deal of attention over the past few decades. However, as was said previously in chapter 3, there have been substantial research gaps in this sector, namely in the selection process of construction when it comes to road construction projects. This topic has been the subject of many articles, and according to the review of the literature that was covered in chapter 2. It is only in extremely unusual circumstances that the suggestions and findings of earlier literature were supported by real-life data to examine how effective and convenient the proposed methodology, criteria, or system is in reality. What can be observed from this review is that the suggestions and findings of earlier literature were supported by real-life data in very rare circumstances. One of the primary reasons for this is that it is difficult and fraught with obstacles to obtaining real-world data because the documents related to the tender are said to be confidential and should not be shared with anyone in order to maintain the integrity and openness of the entire evaluation and awarding process; in this context the firm’s names were named in letters. Nevertheless, the author of this thesis was successful in acquiring real-life data from his home country in order to test and validate the approach that was described in this research.

In this chapter, we will talk about the data, the case study, the outcomes of the case study, and the findings of the case study. It is worth noting that Yemen is a middle eastern country, and the official language is Arabic. Thus, the obtained documents and data are all in Arabic language.

4.2 Data Collection

It was provided to the researcher to assist him with his research and to be able to see the findings of the conducted study. The data that was utilized in this research is confidential information and shall not be shared with anyone. In addition, the type of data that was collected is essentially a tender document for a road-building project in the capital city of Yemen. This project is being carried out by the Yemeni government. In accordance with the law in Yemen, the construction of this road is not regarded to be large because the total distance of the road will not surpass 50 kilometers. However, road construction projects are almost always public projects, and only occasionally are they private projects. As a result, the authority that released these data to the author of this research is comprised of public authorities who are represented by the Public Works and Projects Sector of the General Administration of Central Projects in Sana'a, Yemen. The general specification, the project specification, the award criteria, and details about the project are all included in the first document which was collected. The second file comprises an analysis of the companies that filed the request for tender forms, as well as their comparisons and the prequalification procedure. The rest of the data that was needed for the case study and not mentioned in the official documents that were obtained from the authorities were obtained through personal connections since the firms do not have official websites where they can be reached, and these data are:

Table 4.8: Contractor data needed for proposed system

Contractor/ Criteria	Bid price	Current ratio	No. of years in construction	Experience	Projects completed on schedule	Projects completed on budget	Current workload
A	43886497.5	1.9	9	8	7	8	1
B	43019319.32	2	8	7	5	6	3
C	49790921	1.3	11	14	9	7	3
D	48933755	1.3	15	12	13	12	4
E	48777195	1.7	13	13	10	11	2
F	49594500	1.6	12	11	9	8	1

4.3 Data Analysis

As mentioned earlier, the general specification and the project specification will be discussed briefly. The award criteria and details about the project are all included in the first document, and it will be broken down as follows:

4.3.1 Bill of Quantities of the Project

These data are to be prepared by the tender team and, as shown in figures 4.1and 4.2 that, represent the bill of quantities both in meters and price. This is a form that is available within the tender documents for contractors to fill with prices in order to provide the bidders with the price that the contractor is offering in order to carry out the job. Within the context of this particular tender, these are divided into two parts:

الجمهورية اليمنية
رئاسة الوزراء
امانة العاصمة صنعاء
قطاع الاشغال العامة والمشاريع

جدول الكميات والمواصفات لمشروع / رصف شارع الشهيد أبو حليقة - مديرية الصافية - المناقصة العامة رقم (A5) للعام 2021م

م	بيان الاعمال	الوحدة	الكمية	سعر الوحدة		الإجمالي
				رقما	كتابتا	
1	توريد وتنفيذ اعمال الرصف بالحجر الشيامي المنشور والمرقوم المصندق بسماكة 10 سم و يتم إعتماد العينة قبل التوريد من الادارة تركب بمونة إسمنتية بنسبة (1:3) إسمنت إلى رمل وبسماكة 5 سم وتروب فواصل الحجر بروبة إسمنتية بنسبة خلط (1:1) مع عمل فواصل عرضية كل 10 متر طولي يتم تعبئتها بالبيتومين المخلوط بالرمل والسعر يشمل قلع الاسفلت القديم و القطع إلى منسوب سرير الطريق التصميمي ومن ثم تسوية سرير الطريق في مناطق القطع مع الرش والدك وعمل الاختبارات اللازمة حتى الحصول على كثافة دك لا تقل عن 98% و توريد وفرش طبقة الأساس من المواد المغربلة والمخلوطة بالهلسن (بسكورس) سماكة (15) سم بعد عمل الإختبارات اللازمة لإعتماد المصدر ويتم الفرش والدك حتى الحصول على كثافة دك لا تقل عن 98% , صب خرسانة عادية بسماكة 10 سم وبمقاومة لاتقل عن 180 كجم / سم2 وبمحتوى اسمنتي لا يقل عن 250 كجم/م3 والثمن شامل ترحيل المخلفات الزائدة إلى الأماكن المحددة من قبل أمانة العاصمة وبالتنسيق مع الجهات المختصة	م2	2565			
2	توريد وتنفيذ جسور خرسانية مسلحة عند نهاية الرصف الحجري بابعاد (50*30)سم وحديد تسليح 3علوي و3سفلي قطر14ملم وكانات 5#8مم/متر والثمن يشمل الحفر والتسوية والشدة الخشبية وعمل كل مايلزم لانهاء البند	م3	7			
3	توريد وتنفيذ وتركيب بردورات خرسانية مقاس 60*15*35 سم والسعر يشمل الحفر وعمل قاعدة خرسانية سماكة 10 سم وبعرض لا يقل عن 30 سم أسفل البردورة تسند بساند خرساني حتى ثلثي إرتفاع البردورة وبمقاومة لا تقل عن 250 كجم /سم2 و البند شاملاً نقل المخلفات وعمل الاختبارات اللازمة و بحسب المواصفات و تعليمات المهندس المشرف	م ط	75			
4	توريد وتنفيذ بلاط اسمنتي ملون نوعية ممتازة للارصفة والجزر الوسطية مقاس 30*30*3 سم بعد عمل الاختبارات اللازمة واعتماد العينة من الادارة والثمن يشمل تسوية موقع العمل بالحفر او الردم ورفع اي مخلفات فوق الارصفة وذلك للوصول الى منسوب سرير الرصيف ومن ثم الدك والرش والتسوية وتنفيذ خرسانة عادية بسماكة 5 سم وفرش طبقة الهلسن وتنفيذ المونة الاسمنتية تحت البلاط 3سم مع الرش وعمل جميع ما يلزم بحسب المواصفات والرسومات	م2	173			
	اجمالي الصفحة الأولى					

Figure 4.6: Quantities list 1

الجمهورية اليمنية
رئاسة الوزراء
امانة العاصمة صنعاء
قطاع الاشغال العامة والمشاريع

جدول الكميات والمواصفات لمشروع / رصف شارع الشهيد أبو حليقة - مديرية الصافية - المناقصة العامة رقم (A5) للعام 2021م

م	بيان الاعمال	الوحدة	الكمية	سعر الوحدة		الإجمالي
				رقما	كتابتا	
1	توريد وتنفيذ اعمال الرصف بالحجر الشيامي المنشور والمرقوم المصندق بسماكة 10 سم و يتم إعتماد العينة قبل التوريد من الادارة تركب بمونة إسمنتية بنسبة (1:3) إسمنت إلى رمل وبسماكة 5 سم وتروب فواصل الحجر بروبة إسمنتية بنسبة خلط (1:1) مع عمل فواصل عرضية كل 10 متر طولي يتم تعبئتها بالبيتومين المخلوط بالرمل والسعر يشمل قلع الاسفلت القديم و القطع إلى منسوب سرير الطريق التصميمي ومن ثم تسوية سرير الطريق في مناطق القطع مع الرش والدك وعمل الاختبارات اللازمة حتى الحصول على كثافة دك لا تقل عن 98% و توريد وفرش طبقة الأساس من المواد المغربلة والمخلوطة بالهلسن (بسكورس) سماكة (15) سم بعد عمل الإختبارات اللازمة لإعتماد المصدر ويتم الفرش والدك حتى الحصول على كثافة دك لا تقل عن 98% , صب خرسانة عادية بسماكة 10 سم وبمقاومة لاتقل عن 180 كجم / سم2 وبمحتوى اسمنتي لا يقل عن 250 كجم/م3 والثمن شامل ترحيل المخلفات الزائدة إلى الأماكن المحددة من قبل أمانة العاصمة وبالتنسيق مع الجهات المختصة	م2	2565			
2	توريد وتنفيذ جسور خرسانية مسلحة عند نهاية الرصف الحجري بابعاد (50*30)سم وحديد تسليح 3علوي و3سفلي قطر14ملم وكانات 5#8مم/متر والثمن يشمل الحفر والتسوية والشدة الخشبية وعمل كل مايلزم لانهاء البند	م3	7			
3	توريد وتنفيذ وتركيب بردورات خرسانية مقاس 60*15*35 سم والسعر يشمل الحفر وعمل قاعدة خرسانية سماكة 10 سم وبعرض لا يقل عن 30 سم أسفل البردورة تسند بساند خرساني حتى ثلثي إرتفاع البردورة وبمقاومة لا تقل عن 250 كجم /سم2 و البند شاملاً نقل المخلفات وعمل الاختبارات اللازمة و بحسب المواصفات و تعليمات المهندس المشرف	م ط	75			
4	توريد وتنفيذ بلاط اسمنتي ملون نوعية ممتازة للارصفة والجزر الوسطية مقاس 30*30*3 سم بعد عمل الاختبارات اللازمة واعتماد العينة من الادارة والثمن يشمل تسوية موقع العمل بالحفر او الردم ورفع اي مخلفات فوق الارصفة وذلك للوصول الى منسوب سرير الرصيف ومن ثم الدك والرش والتسوية وتنفيذ خرسانة عادية بسماكة 5 سم وفرش طبقة الهلسن وتنفيذ المونة الاسمنتية تحت البلاط 3سم مع الرش وعمل جميع ما يلزم بحسب المواصفات والرسومات	م2	173			
	اجمالي الصفحة الأولى					

Figure 4.7: Quantities list 2

4.3.2 The Drawings and Pictures of the Project

This gives an idea of the project as it contains pictures of the street taken using a satellite, and it discusses the nature of the project and the land at the site as well.

Figure 4.8: Project picture from a satellite

4.3.3 The General Technical Specifications

1- Soil works

This part of the tender documents covers the whole executing procedures from beginning to finish. It specifies how the work should be done and according to which code will test be carried out. This work covers cleaning the site from any waste within the area of the workplace, protecting the plants and other things that are mentioned not to damage, to finishing and cleaning the whole site to be ready for use. It starts by describing the excavation work and backfilling and how these should be prepared. The California bearing ratio (C.B.R) should not be less than 25%, and the Plasticity Index (PI) should not exceed 10. The PI is the difference between the Liquid Limit and the Plastic Limit (PI = LL – PL). The compaction factor of the soil should not be less than 95% of the ultimate dry compaction factor. According to the contract, the tests stated shall be performed every 100 meters. However, In the case the soil of the site is not good for usage, then another soil is brought into the field and

should be approved by the engineers for the backfilling process. The borrowed soil should satisfy the following:

i. California Bearing Ratio >30%

ii. Liquid Limit <25

iii. Plasticity Index <6

2- Sub-base

This covers the placing of aggregates on a prepared soil surface according to the bill of quantities that are attached to this tender file and in accordance to the specification of this tender. They should satisfy the following conditions:

i. Liquid Limit<25

ii. Plasticity Index I ≤ 4

iii. Compaction Factor 100%

iv. California Bearing Ratio test ≥ 80%

v. Los Angles abrasion test ≤ 30%.

And sieve analysis for the materials of sub-base shall conform to the following table:

Table 4.9: Sieve analysis for sub-base materials

Seive No.	2.5	2	1.5	1	3/4	1/2	4	10	40	200
% Passing	100	90-100	60-90	42-77	35-70	25-60	15-40	10-26	5-15	2-9

3- Surface treatment with bitumen

i. Phase1 (MC)

This type of work means spraying a preparatory layer of medium liquid asphalt (MC) on the surface of the substrate that was prepared in accordance with the specification

of the tender. The followed code in Yemen Road works for testing is the AASHTO code (American Association of State Highway and Transportation Officials).

The following results shall be obtained from preforming the mentioned tests for the MC layer:

AASHTO T79 = 100 Degrees Celsius

AASHTO T72= 75-150 Seconds

AASHTO T44= 99.5%

ii. Phase 2 (RC)

This type of work means spraying a preparatory of Quick-Freezing Liquid Asphalt RC on the surface of the substrate that was prepared in accordance with the specification of the tender. This comes on top of the MC layer. The followed code in Yemen Road works for testing is the AASHTO code (American Association of State Highway and Transportation Officials). The following results shall be obtained from performing the mentioned tests for the RC layer:

AASHTO T79= 80 Degrees Celsius

AASHTO T72= 100-200 Seconds

AASHTO T44= 99.5%

4- Bitumen base layer

The work consists of mixing the asphalt in a mixing plant to ensure a uniform mixture, laying and spraying the asphalt layer, compaction this layer on the sub-base layer, and taking samples for testing to ensure quality control. Formula Job Mix is the used design mix for this stage, and the followed code is AASHTO. The following conditions shall be followed:

i- Filling material sieve analysis

Table 4.10: Sieve analysis for asphalt fillers

Seive number	% passing by weight
No. 30(0.6mm)	100
No.50(0.3mm)	95-100
No.200(0.75mm)	70-100

ii- Asphalt properties:

a) Temperature 60-70 degrees Celsius
b) Burning temperature 232.2 Celsius (Cleveland open-cup method)
c) Melting point 99.5%

The information and specification mentioned here in this chapter are a brief idea of what is mentioned in the tender documents by the tendering committee in which the contractor is obligated to follow this instruction to assure quality control of the project. The reason behind writing these parameters in this part of this research is not to question this data but merely to show how the tender process actually is to have a better idea on the case study. However, the quality bond shall be submitted by the winner within 15 days, which represents 10% of the contract cost, and should be refunded to the contractor after 28 from delivery.

5- Equipment

Table 4.11: Equipment needed for the project

Type	Quantity	Condition
Loader	1	Good
Grider	1	Good
Excavator	1	Good
Bobcat	1	Good

Road roller	1	Good
Water tanker	1	Good
Asphalt cutter	1	Good
Dumping Truck	1	Good

The equipment needed for the project is mentioned in the above table. It says that the number of equipment needed for this kind of project is eight, which is the minimum. Any contractor is willing to submit a tender and should have this number of equipment that ranges from trucks, water tanks, backhoes, and excavators.

6- Experience of Key personnel

Table 4.12: Technical team qualifications and experience

Position	**Qualification**	**Experience**
Project manager	B.S. Civil Engineering	7 years
Material engineer	B.S. Civil Engineering	5 years
Surveyor	DI in Surveying	5 years

Three technical staff are considered for this project that the contractor should have; their education and experience are mentioned as well.

7- Safety

In terms of safety, the tendering documents specify that the contractor should take full responsibility for the personnel safety and sub-contractors if involved in this kind of work in which the contractor is obligated to provide safety measures and insurance.

4.3.4 Prequalification Stage

The number of contractors who participated in the tender was seven contractors. The prequalification stage in Yemen tendering process is evaluating the eligibility of the contractor in participation, in which their legal papers and bond submitted are all evaluated. The tendering committee must justify the reason if they decide to disqualify any contractor. Among these seven contractors, one contractor was disqualified, and the reason behind his disqualification as stated:

Table 4.13: Disqualification of contractor G

Bid No.	**Name of contractor**	**Reason of exclusion**
Bid No. (7)	G	Excluded for the following reasons: -The currency of the bond is in US dollars, which is a different currency for what was specified in the tender documents -The value of the submitted bond is $2,200 which is less than the value of the required bond (according to the official dollar rate of the central bank of Yemen) According to Article 182 of the Law, Tenders and Auctions Paragraph, which defines the cases for excluding bids as follows: -The bond that does not meet the legal requirements specified in the tender documents -Non-renewal of the tax card, Non-presentation of the Zakat card, Non-renewal of the insurance card, Non-submission of a certificate of practicing the profession, Non-renewal of the commercial register.

4.3.5 The Financial Analysis of Contractors

The summary of the financial analysis of the contractors is presented in the following table:

Table 4.14: Financial analysis of contractors

Bidder name	Submitted bids amount (YE Riyal)		Number of arithmetic corrections		Amount of the un-priced elements	The total value of the evaluated bid		Final amount
	Discount %	Bid's amount before discount	(+)	(-)		Before discount	After discount	
A	10%	48,762,775	_	_	_	48,762,775	43,886,497.5	43,886,497
B	12%	48,885,079	39	205 3.42	_	48,885,590.14	43,019,319.3	43,019,319
C		49,790,921	_	_	_	49,790,921	49,790,921	49,790,921
D		48,933,755	_	_	_	48,933,755	48,933,755	48,933,755
E		48,777,195	_	_	_	48,777,195	48,777,195	48,777,195
F		49,594,500	_	_	_	49,594,500	49,594,500	49,594,500

It has been determined that Contractor B provided the lowest price of 43,019,319 Riyal, which was a discount of 12% off the total estimated cost that he provided. Both Contractor A and Contractor B have the best pricing. Contractor B made an error in some calculations, and the committee found it and fixed it. However, the committee stated that the amount of the fix could not be more than 5 percent, or else he shall be disqualified. The experts and members of the tender committee came to a conclusion during the preparation process of the tender documents that the project would cost a total of 50,478,034.00 Riyals. The bids submitted by the six contractors came in cheaper than those estimated, and the figure that follows presents an illustration of how much lower their bids were than the estimated total.

According to Yemen Law of tender 2007, the lowest offered shall be chosen to execute the work, so according to the Yemen rules and regulations, the ranking of the contractors will be as follows:

Table 4.15: Ranking of contractors according to traditional practice

Rank	The bidder's name	The value of the evaluated bid after correction	Discount percentage	The amount after the discount
1	B	48,885,590.14	12%	43,019,319.32
2	A	48,762,775	10%	43,886,497.50
3	E	48,777,195.00		48,777,195.00
4	D	48,933,755.00		48,933,755.00
5	F	49,594,500.00		49,594,500.00
6	C	49,790,921.00		49,790,921.00

Since the law in Yemen states that the award criteria are based on the lowest price in which the price criteria are given 100%, contractor B was selected without considering whether this contractor is financially stable, his current workload, experience...etc. This led to a cost overrun cost of the project, which was due to schedule.

4.4 The Proposed System

4.4.1 Ranking Alternatives Using TOPSIS

The following results were obtained after implementing the method through the proposed system. Firstly, constructing the decision matrix:

Table 4.16: TOPSIS decision matrix

Contractor/ Criteria	Bid price	Current ratio	No. of years in construction	Experience	Projects completed on schedule	Projects completed on budget	Current workload
A	43886497.5	1.9	9	8	7	8	1

B	43019319.32	2	8	7	5	6	3
C	49790921	1.3	11	14	9	7	3
D	48933755	1.3	15	12	13	12	4
E	48777195	1.7	13	13	10	11	2
F	49594500	1.6	12	11	9	8	1

Secondly, Normalization of decision matrix

Table 4.17: Normalized matrix TOPSIS

Contractor /Criteria	**Bid price**	**Current ratio**	**No. of years in construction**	**Experience**	**Projects completed on schedule**	**Projects completed on budget**	**Current workload**
A	0.377866	0.468600	0.3174	0.293491	0.311495	0.365911	0.15811
B	0.370400	0.493263	0.2821	0.256805	0.222497	0.274433	0.47434
C	0.428704	0.320621	0.3879	0.513610	0.400494	0.320172	0.47434
D	0.421323	0.320621	0.5290	0.440237	0.578492	0.548867	0.63245
E	0.419975	0.419274	0.4584	0.476923	0.444994	0.503128	0.31622
F	0.427012	0.394610	0.4232	0.403550	0.400494	0.36591	0.15811

After that, compute the weighted normalized choice matrix and identify both positive ideal and negative ideal solutions (A+, A-). Make use of the weights listed in Table 3.3.

Table 4.18: TOPSIS weighted normalized matrix

Contractor/ Criteria	Bid price	Current ratio	No. of years in cons	Experience	Projects completed on time	Projects completed on budget	Current workload
A	0.2645	0.0234300	0.0158702	0.0146745	0.0155747	0.0121969	0.0079056
B	0.2592	0.0246631	0.0141069	0.0128402	0.0111248	0.0091476	0.0237170
C	0.3000	0.0160310	0.0193970	0.0256805	0.0200247	0.0106723	0.0237170
D	0.2949	0.0160310	0.0264504	0.0220118	0.0289246	0.0182953	0.0316227
E	0.2939	0.0209637	0.0229237	0.0238461	0.0222497	0.0167707	0.0158113
F	0.2989	0.0197305	0.0211603	0.0201775	0.0200247	0.0121969	0.0079056
A+	0.2592	0.02466	0.026450	0.02568	0.02892	0.01829	0.007905
A-	0.3000	0.01603	0.01410	0.01284	0.01112	0.00914	0.03162

Lastly, Calculate the distances between the positive ideal solution and the negative ideal solution (di+,di-), as well as the positive ideal solution's relative closeness (Ri), where the alternative with the closest distance to ideal solution and farthest distance to negative solution is desired.

Table 4.19: Positive and negative TOPSIS

Contractor	di+	di-	di+ + di-	Ri	Rank
A	0.021847592	0.043808725	0.065656317	0.667243105	1
B	0.031108638	0.04245824	0.073566878	0.577137991	2
C	0.046661254	0.018354552	0.065015807	0.282309076	6
D	0.043831001	0.025762049	0.06959305	0.370181346	5
E	0.036649286	0.026313514	0.0629628	0.417921593	3
F	0.042064904	0.027743114	0.069808019	0.397420165	4

4.5 Results and Discussion

The results obtained after using the proposed system by the researcher of this thesis were different than those from the traditional method. However, generally for the proposed system, the weightage of criteria has a significant influence on the results. Still, given the weights of criteria used in this research, the outcomes were different in which the tender shall be awarded to contractor B, who proposed the second-lowest price, on the other hand, the traditional practice says that the tender shall be awarded to the lowest price which in our case is contractor A. Table 4.13 shows the difference in ranking for both methods. Contractor C, which proposed the highest price, was ranked the last in both methods.

Table: 4.20: Comparison of results

Contractor	**Price**	**Traditional system ranking**	**Proposed system ranking**
A	43,886,497.5	2	1
B	43,019,319.32	1	2
C	49,790,921	6	6
D	48,933,755	4	5
E	48,777,195	3	3
F	49,594,500	5	4

4.6 Summary

The findings of this chapter provided evidence that the proposed structure for the contractor selection approach is valid. The purpose of the validation was to carry out a case study and acquire findings to compare traditional practice and the suggested

framework. In the following chapter, a conclusion with recommendations and future works will be discussed.

Chapter 5

CONCLUSION, RECOMMENDATION AND FUTURE WORK

5.1 Introduction

The following study was carried out to identify the variables that affect contractor selection and guarantee the project's success. In order to develop a contractor selection model that can be utilized on a consistent basis for road construction projects in Yemen, the AHP and the TOPSIS were applied as a framework as part of the development process. The outcomes that were obtained from the literature research, the data that was gathered, and the case study that was performed demonstrated that the parameter Price Bid is not the only criterion that clients depend on when choosing the competent contractor. The decision of which contractor is the most qualified is also influenced by a number of other factors. In order to ensure that the award is given to the most qualified applicant, it is necessary to take into account all relevant variables when evaluating the various components of the contractor's bids. As a result, the objective of the contractor selection model that has been suggested as a result of this research is to enhance the awarding phase, which will ultimately lead to a successful completion of the road building project. It is guaranteed that the decision that is made with the help of the suggested model will be superior to the decision that is made when employing the standard contractor selection approaches. This is achieved by applying the model that has been proposed.

5.2 Conclusions

The following findings were reached after doing an analysis of the literature review as part of this research and gathering the data from the case study as a result of this process of putting the suggested framework into action:

- The essential criteria necessary for the selection process and the selection method were developed after a considerable effort and effort was spent doing research, analyzing local practices, and reviewing relevant literature. The selection process was discovered through the literature study, while the criteria that are taken into consideration for local projects were selected based on the judgments of experts in the area.
- The old techniques that are used need to be updated so that they can fit the local conditions, and this is the reason why the proposed model is being established in this study. The old techniques that are used need to be updated so that they can fit the local conditions since the projects are more complex now and considering the price only is not effective. This is the reason why the proposed model is being established in this study.
- The following factors were considered when making the decision: bid price, work capital, number of years spent in the construction industry, experience working on projects with a comparable scope, projects completed on schedule, projects completed within budget, and number of projects currently being worked on.

- The weights of these criteria are to be determined through the proposed system depending on the project nature by the experts in the field judgment using AHP.
- The ranking and the selection of contractors is to be selected using TOPSIS, which uses the weights generated by AHP in earlier stage throughout the system.
- The results obtained from the performed case study are different from the ones using the traditional practice in which the selected contractor using the proposed system came ranked 2 in the traditional practice.

5.3 Recommendations for Using the Proposed System

A list of suggestions based on the findings of the performed study will be presented in this section:

- The author of this research recommends that the criteria applied in the proposed selection model of this research should be used as a solid base for the selection process of contractors in road construction projects
- The author recommends that the non-price criteria that are hard to evaluate shall be stated in the contract clause
- The author recommends using the system as a whole to get the full advantage in the evaluation and selection process
- The author recommends using this system to avoid the risk of the low-price award and to ensure the best value for the money

5.4 Future Works

In this section, a list of probable future works is provided

- The purpose of this project is to carry out research on the application and influence, in terms of decision making, of both traditional techniques and

modern quantitative methodologies, on the levels of performance and efficiency in public and private organizations.

- To conduct similar research to enhance the selection procedure in different project types such as dams, buildings…etc.
- To conduct questionnaires and interviews in order to have a full idea of the suitable criteria for different project types in different countries, use the proper set of criteria.

REFERENCES

Abdelrahman, M., Asce, M., Zayed, T., & Elyamany, A. (2008). Best-Value model based on project specific characteristics. *Journal of construction engineering and management 134(3)*. https://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-9364%282008%29134%3A3%28179%29

Abdelrahman, M., Zayed, T., Hietpas, J. J., & Elyamany, A. (2008). Rational best-value model based on expected performance. *Transportation Research Record, 2081*, 46–55. https://doi.org/10.3141/2081-05

Abdullah, L., Chan, W., & Afshari, A. (2019). Application of PROMETHEE method for green supplier selection: a comparative result based on preference functions. *Journal of Industrial Engineering International, 15*. https://doi.org/10.1007/s40092-018-0289-z

Al Al-Harbi, Subhi. (2001). Application of the AHP in project management. *International journal of project management 19(1)*. https://doi.org/10.1016/S0263-7863(99)00038-1

Amiri, M. P. (2010). Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods. *Expert Systems with Applications*, *37*(9), 6218–6224. https://doi.org/10.1016/J.ESWA.2010.02.103

Araújo, M. C. B., Alencar, L. H., & Mota, C. M. M. (2019). Decision criteria for contractor selection in construction industry: A Literature review. *IEEE International Conference on Industrial Engineering and Engineering Management*, *2019-December*, 637–640. https://doi.org/10.1109/IEEM.2018.8607809

Aruldoss, M., Lakshmi, T. M., & Prasanna Venkatesan, V. (2013). A survey on multi criteria decision making methods and its applications. *American Journal of Information Systems*, *1*(1), 31–43. https://doi.org/10.12691/ajis-1-1-5

Ashworth, A. (1998). *Civil Engineering Contractual Procedures (1st ed.). Routledge*. https://doi.org/10.4324/9781315843148

Ashworth, A. (2008). *Pre-contract studies : development economics, tendering, and estimating*. *364*. https://g.co/kgs/kP33KG

Bennett, F.L. (2003). The management of construction: A project life cycle approach (1st ed.). Routledge. https://doi.org/10.4324/9780080496214

Bochenek, J. (2014). The contractor selection criteria in open and restricted procedures in public sector in selected EU countries. *Procedia Engineering*, *85*, 69–74. https://doi.org/10.1016/j.proeng.2014.10.530

CDM 2015 - Designing buildings. (n.d.). Retrieved May 7, 2022, from https://www.designingbuildings.co.uk/wiki/CDM_2015

Chan, A. P. C., Scott, D., & Lam, E. W. M. (2002). Framework of success criteria for design/build projects. *Journal of Management in Engineering*, *18*(3), 120–128. https://doi.org/10.1061/(ASCE)0742-597X(2002)18:3(120)

Cheaitou, A., Larbi, R., & al Housani, B. (2019). Decision making framework for tender evaluation and contractor selection in public organizations with risk considerations. *Socio-Economic Planning Sciences*, *68*. https://doi.org/10.1016/j.seps.2018.02.007

Chen, C. F. (2006). Applying the analytical hierarchy process (AHP) approach to convention site selection. *Journal of Travel Research*, *45*(2), 167–174. https://doi.org/10.1177/0047287506291593

Cheng, E. W. L., & Li, H. (2010). Contractor selection using the Analytic Network Process. *Http://Dx.Doi.Org/10.1080/0144619042000202852*, *22*(10), 1021–1032. https://doi.org/10.1080/0144619042000202852

Chiang, F.-Y., F. Yu, V., & Luarn, P. (2017). Construction contractor selection in Taiwan using AHP. *International Journal of Engineering and Technology*, *9*(3), 211–215. https://doi.org/10.7763/IJET.2017.V9.972

Creuza Borges De Araújo, M., Hazin Alencar, L., Maria, C., & Mota, M. (2017). Project procurement management: A structured literature review. *International Journal of Project Management*. https://doi.org/10.1016/j.ijproman.2017.01.008

Darvish, M., Yasaei, M., & Saeedi, A. (2009). Application of the graph theory and matrix methods to contractor ranking. *International Journal of Project Management*, *27*(6), 610–619. https://doi.org/10.1016/J.IJPROMAN.2008.10.004

De Keyser, W., & Peeters, P. (1996). A note on the use of PROMETHEE multicriteria methods. In *European Journal of Operational Research* (Vol. 89). https://www.sciencedirect.com/science/article/abs/pii/0377221794003076

Doloi, H. (2009). Analysis of pre-qualification criteria in contractor selection and their impacts on project success. *Construction Management and Economics*, *27*(12), 1245–1263. https://doi.org/10.1080/01446190903394541

El-Abbasy, M. S., Zayed, T., Ahmed, M., Alzraiee, H., & Abouhamad, M. (2013). Contractor selection model for highway projects using integrated simulation and Analytic Network Process. *Journal of Construction Engineering and Management*, *139*(7), 755–767. https://doi.org/10.1061/(asce)co.1943-7862.0000647

Elyamany, A. H., Abdelrahman, M., & Zayed, T. (2012). Utilizing random performance records in the Best Value model. *Journal of Civil Engineering and Management*, *18*(2), 197–208. https://doi.org/10.3846/13923730.2012.671279

Elyamany, A., Abdelrahman, M., & Asce, M. (2010). Contractor performance evaluation for the Best Value of superpave projects. *Journal of construction*

engineering and management 136(5). https://doi.org/10.1061/ASCECO.1943-7862.0000158

Enhancing integrity in public procurement in Yemen OECD joint learning study. (2009). www.oecd.org

Escobar, M. T., & Moreno-Jiménez, J. M. (2007). Aggregation of individual preference structures in AHP-group decision making. *Group Decision and Negotiation*, *16*(4), 287–301. https://doi.org/10.1007/s10726-006-9050-x

Extreme road-building in Yemen: Pictures - Global construction review. (2021). https://www.globalconstructionreview.com/extreme-road-building-in-yemen-pictures/

Forman, E., & Penman, K. (1996). Aggregating individual judgments and priorities with the analytic hierarchy process. *European journal of operational research 108(1).* https://www.sciencedirect.com/science/article/abs/pii/S0377221797002440

Graner, J. (2014). *Tendering strategies*. www.rics.org

Hafizah Mohamed, N., Lamsali, H., & Sathyamoorthy, D. (2017). Technical tender evaluation using analytical hierarchy process (AHP). *Defence s and t technical Bulletin 10(1).* https://www.researchgate.net/publication/316283727_Technical_tender_evaluation_using_analytical_hierarchy_process_AHP

Hasnain, M., Thaheem, M. J., & Ullah, F. (2018). Best Value contractor selection in road construction projects: ANP-based decision support system. *International Journal of Civil Engineering*, *16*(6), 695–714. https://doi.org/10.1007/s40999-017-0199-2

Hashemi, H., Mousavi, S. M., Zavadskas, E. K., Chalekaee, A., & Turskis, Z. (2018). A new group decision model based on grey-intuitionistic fuzzy-ELECTRE and VIKOR for contractor assessment problem. *Sustainability 2018, Vol. 10, Page 1635*, *10*(5), 1635. https://doi.org/10.3390/SU10051635

Hashemi, S. S., Hajiagha, S. H. R., Zavadskas, E. K., & Mahdiraji, H. A. (2016). Multicriteria group decision making with ELECTRE III method based on interval-valued intuitionistic fuzzy information. *Applied Mathematical Modelling*, *40*(2), 1554–1564. https://doi.org/10.1016/J.APM.2015.08.011

Hatush, Z., & Skitmore, M. (1997). Evaluating contractor prequalification data: Selection criteria and project success factors. In *Construction Management and Economics* (Vol. 15, Issue 2, pp. 129–147). Routledge. https://doi.org/10.1080/01446199700000002

Hatush, Z., & Skitmore, M. (2010). Criteria for contractor selection. *Construction management and economics 15(1), 19–38.* https://doi.org/10.1080/014461997373088

Holt, G. (2010). Contractor selection innovation: Examination of two decades published research. *Construction Innovation*, *10*(3), 304–328. https://doi.org/10.1108/14714171011060097

Holt, G. D. (1998). Which contractor selection methodology? . *International Journal of Project Management* 16(3). https://doi.org/10.1016/S0263-7863(97)00035-5

Hosny, O., Nassar, K., & Esmail, Y. (2013). Prequalification of Egyptian construction contractors using fuzzy-AHP models. *Engineering, Construction and Architectural Management*, *20*(4), 381–405. https://doi.org/10.1108/ECAM-09-2011-0088

How roads support development. (2015). Retrieved April 23, 2022, from https://blogs.worldbank.org/developmenttalk/how-roads-support-development

Huang, W.-C., & Chen, C.-H. (2005). Using the ELECTRE II method to apply and analyze the differentiation theory. https://www.researchgate.net/publication/241735610

Hung, C.-C., & Chen, L.-H. (2009). A Fuzzy TOPSIS decision making model with entropy weight under intuitionistic fuzzy environment. *International MultiConference of Engineers and Computer Scientists : IMECS 2009 : 18-20 March, 2009, Regal Kowloon Hotel, Kowloon, Hong Kong*. Newswood Ltd. http://www.iaeng.org/publication/IMECS2009/

Jafari, A. (2013). A contractor pre-qualification model based on the quality function deployment method. *Construction Management and Economics*, *31*(7), 746–760. https://doi.org/10.1080/01446193.2013.825045

Jahanshahloo, G. R., Lotfi, F. H., & Izadikhah, M. (2006). An algorithmic method to extend TOPSIS for decision-making problems with interval data. *Applied Mathematics and Computation*, *175*(2), 1375–1384. https://doi.org/10.1016/J.AMC.2005.08.048

Jaskowski, P., Biruk, S., & Bucon, R. (2010). Assessing contractor selection criteria weights with fuzzy AHP method application in group decision environment. *Automation in Construction*, *19*(2), 120–126. https://doi.org/10.1016/J.AUTCON.2009.12.014

Jato-Espino, D., Castillo-Lopez, E., Rodriguez-Hernandez, J., & Canteras-Jordana, J. C. (2014). A review of application of multi-criteria decision making methods in construction. *Automation in Construction*, *45*, 151–162. https://doi.org/10.1016/J.AUTCON.2014.05.013

Jiang, C. Z., & Yan, Z. (2010). Application of TOPSIS analysis method based on AHP in bid evaluation of power equipment. *2010 2nd IEEE International Conference on Information and Financial Engineering.* IEEE. 10.1109/ICIFE.2010.5609280

Kahraman, C., Engin, O., Kabak, Ö., & Kaya, I. (2009). Information systems outsourcing decisions using a group decision-making approach. *Engineering*

Applications of Artificial Intelligence, *22*(6), 832–841. https://doi.org/10.1016/J.ENGAPPAI.2008.10.009

Kashiwagi, D., & Byfield, R. E. (2002). Selecting the best contractor to get performance: On time, on budget, meeting quality expectations. *Journal of Facilities Management*, *1*(2), 103–116. https://doi.org/10.1108/14725960310807872

Khoso, A. R., & Yusof, A. M. (2020). Extended review of contractor selection in construction projects. In *Canadian Journal of Civil Engineering* (Vol. 47, Issue 7, pp. 771–789). Canadian Science Publishing. https://doi.org/10.1139/cjce-2019-0258

Kim, J. Y., & Han, J. H. (2016). Straw effects of new highway construction on local population and employment growth. *Habitat International*, *53*, 123–132. https://doi.org/10.1016/J.HABITATINT.2015.11.009

Krejčí, J., & Stoklasa, J. (2018). Aggregation in the analytic hierarchy process: Why weighted geometric mean should be used instead of weighted arithmetic mean. *Expert Systems with Applications*, *114*, 97–106. https://doi.org/10.1016/j.eswa.2018.06.060

Ksiazek, M., & Ciechowicz, P. (2016). Selection of the general contractor using the AHP method. *Archives of Civil Engineering*, *62*(3), 105–116. https://doi.org/10.1515/ACE-2015-0086

Lam, K. C., Palaneeswaran, E., & Yu, C. yun. (2009). A support vector machine model for contractor prequalification. *Automation in Construction*, *18*(3), 321–329. https://doi.org/10.1016/J.AUTCON.2008.09.007

Lambropoulos, S. (2007). The use of time and cost utility for construction contract award under European Union Legislation. *Building and Environment*, *42*(1), 452–463. https://doi.org/10.1016/j.buildenv.2005.08.002

Liu, B., Huo, T., Liao, P. chao, Yuan, J., Sun, J., & Hu, X. (2016). A special Partial Least Squares (PLS) path decision modeling for bid evaluation of large construction projects. *KSCE Journal of Civil Engineering 2017 21:3*, *21*(3), 579–592. https://doi.org/10.1007/S12205-016-0702-3

Mahdi, I. M., Riley, M. J., Fereig, S. M., & Alex, A. P. (2002). A multi-criteria approach to contractor selection. *Engineering, Construction and Architectural Management*, *9*(1), 29–37. https://doi.org/10.1108/EB021204/FULL/XML

Mareschal, B., Brans, J. P., & Vincke, P. (1984). Prométhée: a new family of outranking methods in multicriteria analysis. *ULB Institutional Repository*, *477-490*. https://ideas.repec.org/p/ulb/ulbeco/2013-9305.html

Martin, H., Koylass, J., & Welch, F. (2018). An exploration of the consistency limits of the analytical hierarchy process and its impact on contractor selection. *International Journal of Construction Management*, *18*(1), 14–25. https://doi.org/10.1080/15623599.2016.1230954

Mills, A. (2011). The impact of client attitudes on the selection of contractors. *Malaysian construction research journal 8(1):88-102*. http://hdl.handle.net/10536/DRO/DU:30044311

Mohammadi, A., Mohammadi, A., & Aryaeefar, H. (2011). Introducing a new method to expand TOPSIS decision making model to fuzzy TOPSIS. *Journal of Mathematics and Computer Science*, *02*(01), 150–159. https://doi.org/10.22436/JMCS.002.01.16

Morledge, Roy., & Smith, A. (2013). Building procurement. 327.

Oad, P. K., Kajewski, S., Kumar, A., & Xia, B. (2021). Investigation of innovation during bid evaluation process in the road construction industry. *Civil Engineering Journal (Iran)*, *7*(3), 594–613. https://doi.org/10.28991/cej-2021-03091676

Oladapo, A. A., & Odeyinka, H. (2006). Tender evaluation methods in construction projects : a comparative case study. *Acta Structilia*, 13(1), pp. 106-131. https://journals.ufs.ac.za/index.php/as/article/view/1577

Opricovic, S., & Tzeng, G. H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research*, *156*(2), 445–455. https://doi.org/10.1016/S0377-2217(03)00020-1

Ossadnik, W., Schinke, S., & Kaspar, R. H. (2016). Group aggregation techniques for Analytic Hierarchy Process and Analytic Network Process: A comparative

analysis. *Group Decision and Negotiation*, *25*(2), 421–457. https://doi.org/10.1007/s10726-015-9448-4

Palaneeswaran, E., & Kumaraswamy, M. M. (2000). Contractor selection for design/build projects. *Journal of Construction Engineering and Management*, *126*(5), 331–339. https://doi.org/10.1061/(ASCE)0733-9364(2000)126:5(331)

Plebankiewicz, E. (2009). Contractor prequalification model using fuzzy sets. *Journal of Civil Engineering and Management*, *15*(4), 377–385. https://doi.org/10.3846/1392-3730.2009.15.377-385

Ramanathan, R., & Ganesh, L. S. (1994). Group preference aggregation methods employed in AHP: An evaluation and an intrinsic process for deriving members' weightages. *European Journal of Operational Research* (Vol. 79). https://ideas.repec.org/a/eee/ejores/v79y1994i2p249-265.html

Rashvand, P., Abd Majid, M. Z., Baniahmadi, M., & Ghavamirad, F. (2015). Contractor selection at prequalification stage: Current evaluation and shortcomings. *Jurnal Teknologi*, *77*(16), 81–89. https://doi.org/10.11113/JT.V77.6403

Roy, R. (2017). Conventional tendering process for construction projects | Tendersinfo Blogs. https://www.tendersinfo.com/blogs/conventional-tendering-process-for-construction-projects/

Saaty, R. W. (1987). The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling*, *9*(3–5), 161–176. https://doi.org/10.1016/0270-0255(87)90473-8

Saaty, T. L. (1988). Decision making for leaders : the analytical hierarchy process for decisions in a complex world. 291.

Sabaei, D., Erkoyuncu, J., & Roy, R. (2015). A review of multi-criteria decision making methods for enhanced maintenance delivery. *Procedia CIRP*, *37*, 30–35. https://doi.org/10.1016/J.PROCIR.2015.08.086

San Cristóbal, J. R. (2012). Contractor selection using multicriteria decision-making methods. *Journal of Construction Engineering and Management*, *138*(6), 751–758. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000488

Sanayei, A., Farid Mousavi, S., Abdi, M. R., & Mohaghar, A. (2008). An integrated group decision-making process for supplier selection and order allocation using multi-attribute utility theory and linear programming. *Journal of the Franklin Institute*, *345*(7), 731–747. https://doi.org/10.1016/J.JFRANKLIN.2008.03.005

Semaan, N., & Salem, M. (2017). A deterministic contractor selection decision support system for competitive bidding. *Engineering, construction and architectural management*, *24*(1), 61–77. https://doi.org/10.1108/ECAM-06-2015-0094

Senthil, S., Srirangacharyulu, B., & Ramesh, A. (2014). A robust hybrid multi-criteria decision making methodology for contractor evaluation and selection in third-

party reverse logistics. *Expert Systems with Applications: An International Journal*, *41*(1), 50–58. https://doi.org/10.1016/J.ESWA.2013.07.010

Shih, H. S., Shyur, H. J., & Lee, E. S. (2007). An extension of TOPSIS for group decision making. *Mathematical and Computer Modelling*, *45*(7–8), 801–813. https://doi.org/10.1016/J.MCM.2006.03.023

Skitmore, M. (2002). Predicting the probability of winning sealed bid auctions: a comparison of models. *Journal of the Operational Research Society*, *53*(1), 47–56. https://doi.org/10.1057/PALGRAVE.JORS.2601236

Smith, A. J. (1995). The Competitive Tendering Process — A Client's View. *Estimating, Tendering and Bidding for Construction*, 191–211. https://doi.org/10.1007/978-1-349-13630-8_14

Sonmez, M., Yang, J. B., & Holt, G. D. (2001). Addressing the contractor selection problem using an evidential reasoning approach. *Engineering Construction and Architectural Management*, *8*(3), 198–210. https://doi.org/10.1046/J.1365-232X.2001.00199.X

Taylan, O., Kabli, M. R., Porcel, C., & Herrera-Viedma, E. (2018). Contractor selection for construction projects using consensus tools and big data. *International Journal of Fuzzy Systems*, *20*(4), 1267–1281. https://doi.org/10.1007/S40815-017-0312-3

Teixeira de Almeida, A. (2007). Multicriteria decision model for outsourcing contracts selection based on utility function and ELECTRE method. *Computers and Operations Research*, *34*(12), 3569–3574. https://doi.org/10.1016/J.COR.2006.01.003

Tender_law_2007 Yemen. (2007).

Thabit, M. A. A. (2019). A working paper on procurement anti-corruption in Yemen. *المجلة العربية للإدارة*, *39*(4), 251–264. https://doi.org/10.21608/aja.2019.66952

Tsai, H.-Y., Huang, B.-H., & Wang, A. S. (2008). Combining ANP and TOPSIS concepts for evaluation the performance of property-liability insurance companies. *Journal of Social Sciences*, *4*(1), 56–61. https://doi.org/10.3844/JSSP.2008.56.61

Ülengin, F., Ilker Topcu, Y., & Şahin, Ş. Ö. (2001). An integrated decision aid system for Bosphorus water-crossing problem. *European Journal of Operational Research*, *134*(1), 179–192. https://doi.org/10.1016/S0377-2217(00)00247-2

Waara, F., & Bröchner, J. (2006). Price and nonprice criteria for contractor selection. *Journal of construction engineering and management 132(8)*. https://doi.org/10.1061/ASCE0733-93642006132:8797

Wardani, M. A. el, Messner, J. I., & Horman, M. J. (2006). Comparing procurement methods for design-build projects. *Journal of Construction Engineering and*

Management, *132*(3), 230–238. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:3(230)

Watt, D. J., Kayis, B., & Willey, K. (2009). Identifying key factors in the evaluation of tenders for projects and services. *International Journal of Project Management*, *27*(3), 250–260. https://doi.org/10.1016/J.IJPROMAN.2008.03.002

Watt, D. J., Kayis, B., & Willey, K. (2010). The relative importance of tender evaluation and contractor selection criteria. *International Journal of Project Management*, *28*(1), 51–60. https://doi.org/10.1016/J.IJPROMAN.2009.04.003

Wu, L. Y., & Yang, Y. Z. (2008). TOPSIS method for green vendor selection in coal industry group. *Proceedings of the 7th International Conference on Machine Learning and Cybernetics, ICMLC*, *3*, 1721–1725. https://doi.org/10.1109/ICMLC.2008.4620683

Zavadskas, E. K., Turskis, Z., & Tamošaitiene, J. (2008). Contractor selection of construction in a competitive environment. *Journal of Business Economics and Management*, *9*(3), 181–187. https://doi.org/10.3846/1611-1699.2008.9.181-187