TWO-STAGE CONTINUOUS ASSESSMENT DECISION SUPPORT MODEL FOR SELECTION OF CONTRACTORS IN PAKISTAN'S PUBLIC PROJECTS

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DEDICATION

All praise to Allah Almighty without His support, indeed nothing is possible. This thesis is dedicated to my beloved parents, who encouraged and supported me in every walk of this journey.

Special thanks to my wife, for her endless love and courage, and for standing with me in all ups and downs during this journey.

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ABSTRACT

Recent massive number of urban construction developments in Pakistan and around the globe have drawn attention to researchers in systematic way of undertaking the project. More importantly, the project‗s team should consist of capable parties especially contractors. In relation to this, it is crucial to select the most competitive contractors and the most systemic approach to the selection which needed to be given serious attention. A plethora of research is carried in the last three decades to develop decision support models in selecting contractors. However, the complexity of contractor selection models is proliferating, and the user-friendly decision system is yet to be developed. In more specific geographical context such as Pakistan, there is very limited work has been done to assess the contractors' capability especially in the public sector. Therefore, this study aims to develop a decision support model for final contractor selection in public construction projects in Pakistan. To accomplish this, the study is underpinned by four objectives. Firstly, to compute the significance of attributes affecting selection of contractor, and the second objective is aim to assess the contractor's selection practices in Pakistan's public sector departments and suggest suitable directions to improve the current process. The third objective aims to compute contractor selection attributes' weightages and performance assessment weightages for contractors' assessment. The fourth objective is to develop a decision support model for the final selection of contractors in Pakistan's public project. A novel triplet hybrid integrated approach of multi-criteria decision-making techniques is applied to analyse the data. A total of seventy-six (76) attributes were analysed, correlated, rotated, and weighted using Exploratory Factor Analysis. Later on, MACBETH is applied to compute the attributes weightages via M-MACBETH software package. Finally, with the help of SMART, the performance assessment grading levels were calculated to assess the contractors which turns into a triplet hybrid model of EFA-MACBETH-SMART. The research computes extensive attributes of contractor selection and classified these into four novel categories such as eligibility, critical, value-added, and desirable criteria. The study also assesses the current contractor selection practices which outlines several common practices including flaws in the system and later suitable directions are suggested. Furthermore, the attributes' weightages are computed using MACBETH, and performance assessment weightages are computed using SMART based on different performance levels. Finally, a two-stages continuous assessment decision support model is developed on technical and financial bid ratio mechanisms based on contractors' performance levels. Findings from the model unveil that continuous assessment from technical stage in final selection make justice with the highly qualified contractors, and the likelihood of project success increases. The developed two-stage model further conclude that technically highest bidders may be awarded the contract if additionally offers a feasible bid. The model improves the current assessment process in assisting clients for making right and justified decisions, keeping the bid price and other technical criteria into consideration. Furthermore, the model selects the most capable contractor with priorities to technical attributes, and besides, the model also preserves the lowest evaluated bid concept which is additional improvement in current assessment process.

ABSTRAK

Pembangunan pesat di bandar yang berlaku di Pakistan serta negara lain diseluruh dunia telah menarik minat penyelidik untuk mengkaji kepentingan kaedah yang sistematik menjalankan projek. Apa yang lebih penting adalah pasukan projek perlu terdiri daripada pihak yang berkeupayaan terutamanya kontraktor. Kajian yang dijalankan sejak tiga (3) dekad yang lalu telah membangunkan model pemilihan kontraktor namun masih tidak terdapat kaedah yang lebih mudah dan mesra pengguna dalam hal ini. Didalam konteks geographi yang lebih khusus seperti Pakistan, kajian bagi menilai keupayaan kontrak terutamanya bagi projek awam amat terhad. Oleh itu, kajian ini dijalankan bagi tujuan membangunkan model yang menyokong pemilihan kontraktor bagi projek awam di Pakistan. Bagi mencapai matlamat ini, empat (4) objektif yang menunjangi kajian ini. Pertama adalah untuk mengira kepentingan atribut yang wajar mempengaruhi pemilihan kontraktor bagi projek pembinaan di Pakistan. Objektif kedua adalah untuk menilai praktis semasa pemilihan kontraktor bagi jabatan awam Pakistan serta mencadangkan penambahbaikkan bagi kaedah semasa. Objektif ketiga adalah untuk mengira pemberat bagi atribut pemilihan kontraktor dan penilaian prestasi kontraktor. Objektif keempat adalah untuk membangunkan model bagi pemilihan akhir kontraktor bagi projek awam di Pakistan. Pendekatan baharu bagi membuat keputusan yang melibatkan kaedah hybrid bersepadu tiga serangkai pelbagai kriteria digunakan untuk menganalisis data yang didapati daripada temu bual, pertemuan bersemuka dan soal selidik. Sejumlah tujuh puluh enam (76) atribut telah dianalisis, dihubungkaitkan, diputar dan diberi pemberat menggunakan Analisis Faktor Penerang (EFA). Kemudian, MACBETH mengira kewajaran bagi atribut dengan menggunakan perisian M-MACBETH. Kajian ini mengira atribut pemilihan kontraktor secara meluas dan mengkelaskan atribut kepada empat (4) kategori baharu iaitu kelayakan, kritikal, nilai-tambah dan kewajaran. Kajian juga menilai praktis semasa pemilihan yang mempunyai kelemahan dan arah sepatutnya dicadangkan. MACBETH digunakan unutk mengira pemberat atribut dan penilaian prestasi kontraktor dikira oleh SMART, yang kedua-duanya dikira pada tahap yang berbeza. Akhirnya satu model dua-peringkat penilaian berterusan yang berasaskan kadar prestasi nisbah bida teknikal dan kewangan kontraktor dibangunkan. Model ini dapat menyokong dalam membuat pemilihan kontraktor. Model mendedahkan penilaian beterusan akan lebih adil kepada kontraktor yang lebih layak dengan itu kebarangkalian projek berjaya adalah lebih tinggi. Model ini menyimpulkan bahawa kontraktor yang berkeupayaan teknikal yang tinggi boleh ditawarkan projek jika bidaan semasa dikemukan boleh dilaksanakan. Model yang dibangunkan ini menambah baik kaedah penilaian semasa dan membantu klien dalam membuat keputusan yang tepat dan adil dengan mengambil kira harga bida dan kriteria teknikal. Model mencadangkan pemilihan kontraktor yang berkeupayaan dengan memberi keutamaan kepada atribut teknikal. Model juga mengekalkan konsep bida terendah sebagai satu penambahbaikkan kaedah penilaian semasa.

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LIST OF ABBREVIATIONS

ADB	-	Asian Development Bank
AHP	-	Analytical Hierarchy Process
A.I	-	Average Index
ANN	-	Artificial Neural Network
ANOVA	-	Analysis Of Variance
ANP	-	Analytical Network Process
ASCE	-	American Society of Civil Engineers
BPPRA	-	Balochistan Public Procurement Regulatory Authority
COPRAS	-	Complex Proportional Assessment of Alternatives
DEA	-	Data Envelopment Analysis
DMs	-	Decision Makers
DSM	-	Decision Support Model
DSS	-	Decision Support System
EC	-	Essential Criteria
EDAS	-	Evaluation Based On Distance From Average Solution
EFA	-	Exploratory Factor Analysis
ELECTRE	-	ELimination Et Choice Translating REality
FL	-	Factor Loading
FS	-	Factor Score
FSS	-	Final Sum Score
GDP	-	Gross Domestic Products
HSE	-	Health, Safety, and Environment
ICE	-	Institute of Civil Engineers
IFS	-	Intuitionistic Fuzzy Set
INGOs	-	International Non-Government Organisations
ISO	-	International Organization for Standardization
IT	-	Information Technology
JICA	-	Japan International Corporation Agency
KMO	-	Kaiser-Meyer-Olkin
LP	-	Linear Programming

MACBETH	-	Measuring Attractiveness by a Categorical Based Evaluation Technique
MAUT	-	Multi-Attribute Utility Theory
MCDM	-	Multi-Criteria Decision Making
MEAT	-	Most Economically Advantageous Tender
NESPAK	-	National Engineering Services, Pakistan
NGOs	-	Non-Government Organisations
NIT	-	Notification for Invitation of Tender
NTN	-	National Tax Number
PCA	-	Principle Component Analysis
PEC	-	Pakistan Engineering Council
PGAL	-	Performance Grading Assessment Level
PGAL-W	-	Performance Grading Assessment Level Weightages
PI	-	Performance Indicator
PKR	-	Pakistani Rupees
PLS	-	Partial Least Square
PPRA	-	Pakistan Procurement Regulatory Authority and Pakistan
PROMETHEE	-	Preference Ranking Organization Method for Enrichment Evaluation
PWD	-	Public Works Department
REC	-	Regional Enrolment Committee
RQ	-	Research Question
SMART	-	Simple Multi-Attribute Rating Technique
SMARTER	-	Simple Multi-Attribute Rating Technique Extended to Ranking
SPPRA	-	Sindh Public Procurement Regulatory Authority
SPSS	-	Statistical Packages of Social Sciences
SS		Sum Score
TOPSIS	-	Technique for Order of Preference by Similarity to Ideal Solution
VIKOR	-	VIekriterijumsko KOmpromisno Rangiranje
WAPDA	-	Water and Power Development Authority
WB	-	World Bank

WoS	-	Web of Science
WSM	-	Weighted Sum Model

LIST OF SYMBOLS

C	-	Semantic scale
α	-	Cronbach's alpha
Ap	-	Amount of lowest bid submitted
As	-	Amount of a bid under consideration
W_j	-	Final weight
U_i	-	Utility value
S_{ij}	-	Scale under consideration
S_{min}	-	Minimum scale value
S_{max}	-	Maximum scale value
r	-	Person's coefficient of product moment correlation
p	-	Significant value
N	-	Total Number of respondents
L	-	Performance level
$R_{T/F}$	-	Technical/financial bid ratio
T_{BS}	-	Technical bid score
F_{BS}	-	Financial bid score
T_{BW}	-	Technical bid weightage
F_{BW}	-	Financial bid weightage

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CHAPTER 1

INTRODUCTION

1.1 Background of Research

The construction industry accounts for symbolic benefaction in the economic and social augmentation of any country. IHS Global Insight (2010) published a report that the annual growth rate of construction worldwide is 3.5% between 2009 and 2014, and this rate for the non- Japan Asian countries is 7.3%. According to a United Nations report, the Gross Domestic Products (GDP) growth of the United States of America (USA) in the construction sector from 2014 to 2016 is 1.8 to 3.3%; however, it is 2.2 to 2.4% for the United Kingdom (UK). As one of the economic sectors, construction provides employment. In the United Kingdom, the construction sector's employment rate increased by 4.6% in 2016 compared to 2015, making this industry the fastest growing industry in the UK compared to agriculture, service, and production (Office for National Statistics, 2017). This industry also significantly contributes to the European economy in terms of Gross Domestic Products (GDP) and employment (Carter, 2009). For the developing and economically emerging countries like China, India, and Malaysia, the GDP growth rate is 9.1%, 4.7%, and 11.7 %, respectively in 2014 (United Nations, 2017). This swift development assumed further than 30% GDP of countries worldwide would be from the construction sector only (Akcay and Manisalı, 2018). Looking above statistics trends of GDP growth, the developing countries are relatively more focusing now towards the construction projects. The advancements in this sector is favourable to the countries around the globe, especially for developing countries as this is the right time to take the opportunities and lower down their economic burden by growing GDP via more targeting the large scale construction projects.

Large-scale projects are significant for a country in terms of its economic, political, and social growth. This development of public works is essential; thus, many governments use their own public procurement process to support the domestic industries and projects (Abdelrahman et al., 2008). This public procurement often constitutes the crowning level of investments in the infrastructures. For example, Moshi (2013) claimed that this investment is around 60-70% of its total government budget. According to a report by OECD (2015), the Australian government spent 35.23% of its budget for procurement, whereas Canada, USA, UK, Germany, South Korea spent 32.39%, 24.94%, 31.39% and 34.23%, 38.89%, respectively, in 2014 and Turkey spent 28.94% in 2011. The prominence of procurement can be perceived from enormous investment in public departments reflecting that procurement is a major part of government budget and many developed and developing countries spending their hefty budget in this phase.

The procurement phase principally integrates the fragmented supply of construction teams such as project managers, engineers, architects, contractors, suppliers, labourers, etc. Thus, many public departments follow a typical procurement process to execute the infrastructure by encompassing the right construction team at the right time at the right stages. Besides, the paradigm shift of advancement in the technology and high-level demands by the clients in the construction sector take along complexity, and like other sectors, this industry is not free from fundamental challenges. To address these issues, Kog and Yaman (2016) pointed out that the construction sector is highly susceptible to the risk and uncertainties and the success in this sector is highly based on the efficient use of resources. Apart from other serious problems, the varied nature of construction projects is worthy of discussing that transported turbulence in this industry for the researcher to continue their work and explore highly constructive and viable solutions. Moreover, the client‘s expectations are ideal; for example, they always look for a high-quality outcome with lesser completion time and cost. Another concern of this industry is; fragile surroundings, the high-level involvement of many stakeholders, and inherent complexity (Ye et al., 2018). The continuation of the aforementioned problems negatively affects the industry and owing to this reason the industry has a poor record of success in terms of cost, time, and quality (Xiong et al., 2014). To avoid the discussed problems in construction projects and to cope with the

several present issues, a client requires efficient resources and highly experienced and professional experts as part of construction projects. Thus, public departments procure the efficient use of resources, equipment, external human skills, materials, etc., from an external sources through a systematic tendering procedure and adhere to them via contracting. In general, a typical tendering begins from the preparation of documents; later, a bid is invited to contractors where after evaluation of contractors and their bids, a client decides to award the work. This extended process is prone to several problems due to its complicated nature. Researchers such as Huang (2011) believes that the risk level is high during the tendering process. Thus, this risk is also pertaining to the selection of contractors because, during this tendering phase, a client selects a contractor to execute its project.

Typically, the clients are either from public or private sector. A public sector is primarily considered a larger sector and normally deals with mega projects. This sector follows the government's regulations and legal boundaries; thus, public tendering is multifarious. While comparing both sectors, Kog et al. (2014) stated that the private sector is less concerned with legal procedures and more flexible towards tendering processes. Whereas, the public projects are more intricate, possessing high social involvement, exceedingly rigid rules and boundaries, diverse nature of work, and stringent tendering process. They also concluded that associated risks are always a matter of concern for the construction clients, and a client requires a highly competitive partner to confront this. In general, private sector clients are reluctant and follow their own tendering process; however, in the public sector, the project bid price is a significant concern due to public accountability. Traditionally, most of the time in the public sector around the globe the award is offered on the lowest bid (Awwad and Ammoury, 2019; Cheaitou et al., 2019). This lowest bid award is a common practice in a competitive bidding system, which is a base of public sector award (Brunjes, 2020). Lo et al. (2007) also mentioned that the competitive bidding system, which is open to all tenderers, has been blamed for abnormally low bid, which is the root cause of poor quality. In contrast, nowadays, clients are looking for the best value of money along with the bid price. Ayoti (2012) states that the tender which offer the best value of money will win the business in public environment. This confrontation between the lowest price and best value of money indulge several years in the public construction history of many countries.

Historically, many researchers believe that the successful project receives the lowest tender price (Topcu, 2004). On the contrary, presently the researcher believe that the traditional lowest price method looks attractive to the client, but in the long term, it has never been a wise choice but a fundamental cause of project failure (Chen et al., 2021). Chee et al. (2001) discourage the lowest bid method and report that time and cost overrun and bad performance are the result from this method. Feldman (2006) supports the idea and emphasises that a long time, higher cost, and poor quality problems are due to this tender approach. According to Fujii and Miyakawa (2016), in the United Kingdom, several conflicts occur between the clients and contractors due to ruthless quality projects because contractors intentionally quote low prices to win the bid as it is solely the criteria to win a bid. At a later stage, the selected contractor reduces the quality; hence, the competent authorities brought deviation in the system by introducing multiple criteria decision systems besides the solo bid price. Similarly, in Australia, it is believed that the lowest price tendering method is the reason for deprived quality outcomes (Olaniran, 2015). In the USA and Canada, the prevailing method of awarding the contract is based on the lowest bid, which results in severe issues of project performance (Awwad and Ammoury, 2019). Author claimed that these problems lead to shifting the industry of the USA and Canada towards quality-based selection.

Persisting many loopholes in the lowest bid price tendering, Brook (2017) criticised the method and suggested that the tendering should never be done on the lowest price alone. Awwad and Ammoury (2019) claimed that no doubt the method is the most accepted, but it does not necessarily result in the project's best performance. In continuation to this, many developed countries are moving forward such as nowadays for large construction projects, the construction industry in USA started a best value contract system, leaving behind the lowest bid (Farooqui et al., 2008). The system includes a multi-criteria selection approach where the contractor expects the value for money rather than to presume the lowest project cost (Taishi and Harada, 2005). Few European countries, for example, France, Spain, Ireland, UK, Portugal, Czech Republic, Italy, Austria, Belgium, Germany, Sweden, and Netherland introduced another method of tendering known as ~~t~~he most economically advantageous tender" (MEAT), and these countries are promoting this procurement method in public works. The characteristics of this method are; bid

price, technical competence, functional characteristics, service and sale techniques, delivery date and period of completion, quality, environmental consideration, the security of supply, and the commitment (Bochenek, 2014). Note that the said practices are in connection to the design-bid-build procurement method.

In public tendering the most ordinarily adopted project delivery method worldwide is design-bid-build (Oyegoke et al., 2009) which involved consultants for planning and designing and preparing the price estimation and assists, clients, preparing documents and specifications. Contractors are involved in executing the intended projects according to the planning and designing based on the contract's specified terms and conditions. Therefore, a contractor is a party that is essentially involved in the execution phase until the successful delivery of a project to the end-user. Besides, the delivery of a project is mostly battered with the severe problems of time, cost, quality, safety, litigations, claims, etc. Since both the client and contractors are involved, they are jointly responsible for the project's success, but mishaps have been put on the contractors as highlighted by (Adnan et al., 2012). Further, Alzahrani and Emsley (2013) reasserted and pointed out that since contractors are involved from the execution stage until its completion, the project's success is closely related to the contractors. Besides this, Xiao and Proverbs (2003) also confirmed that the contractor characteristics are the critical criteria for the healthier performance of the project. Looking at this evidence, the contractor is more responsible for the project outcome than the client or consultant. This further assumes that the construction project has a majority of issues with the incapable contractor.

To deal with the contractors' selection, a client needs to precisely set the evaluation criteria and expected contractor characteristics. Being so important part of the construction, its selection in the project is a major factor contributing to the project's success (Banki et al., 2009; Thomas Ng et al., 2009). In this regard, Polat et al. (2017) claimed that a construction project is extremely dependent on the right selection of human resources with the right skills at the right time. Chotibhongs and Arditi (2012) also believed that contractor selection is a serious concern for the client and claimed that many problems have been obscene when contractors are chosen

without proper considerations. Therefore, any biased decision can be inevitable, so a very transparent decision is the ultimate goal for clients. Unfolding serious concern of right and capable contractors during the tendering process, this selection of contractors turns to be increasingly important for public projects, especially based on multi-criteria alongside bid price criteria.

1.2 Problem Statement

The selection of potential and capable contractor in the public construction sector during the tendering phase of procurement involves the precise decision and its selection subject to its capability regarding technical, commercial, economic, social, and environmental characteristics. These multi-characteristics requirements are making this procedure more complicated. Moreover, due to current diversity and the immense dynamic nature of construction, clients have superfluous high demands, making the tendering process further tedious (El-Abbasy et al., 2013). Thus, the tendering process's objectives bifurcated; to limit the potential bidders in the tendering process and to map the contractor‘s capabilities with the projects. To meet the stated goals, public resources' efficient use is one of the many challenges to public investments. That is why the tendering process is mainly based on the minimum bid as the public sector is always accountable for public funds (Kog et al., 2014). Researchers agreed that this system would not guarantee the maximum output and cause serious problems (Cheaitou et al., 2019), further produces imperfect competition in the market (Brunjes, 2020), and lowers the quality (Chen et al., 2021).

Further, the competency is specific requirements pertaining to the bidder's project, such as specific experience, technical and managerial staff, adequate and desire equipment, etc. (Huang, 2011). This competent part of tendering is not fully understood and addressed; traditionally, the client sets high weight on price and lowers weight on soft parameters (Kadefors, 2005). This process is more specific in public departments (Kumaraswamy and Anvuur, 2008), where the relation between the price and other criteria is not well understood. Pertaining to this problem, the tendering phase of procurement is still facing several crises, and the problem has not

been resolved yet in Pakistan, consequently opening the gates for more research in this area. Currently, the selection of contractor in Pakistan is based on bid price selection, which ignores the concept of multi-criteria assessment. This is primarily because of public accountability where selecting a contractor other than lowest bidder needs very strong justification. Besides, the expertise of contractor is only limited to certain extend i.e., only to prequalify the contractors. Further, the selection criteria are very limited and higher weightage is provided to cost parameter. Therefore, currently in Pakistan, the contractor selection process does not follow the competency of contractor, rather based on price based selection (Khan and Khan, 2015).

In Pakistan, most clients want timely completion of projects with satisfactory quality but at a lower cost (Ali, 2006). Bangash (2016) found that most projects in Pakistan are completed in 11 to 30% overrun of time, and contractors are one of the major reason behind it. Soomro et al. (2019) also found that contractor is one of the major reasons behind the delays in construction projects in Pakistan. Likewise, Hussain et al. (2018) pointed out that the current practices of awarding the contract are one of the main cause behind delays in construction projects. Thus, the time overrun is a prime issue in the industry since long time and contractors are a major reason behind this cause. Haseeb et al. (2011) also claimed that in Pakistan, around 80% of projects are affected with an overrun of time, and only 20% are completed on time, where contractor‘s ill planning, bad experience and poor management policies are the major reason behind this.

Apart from the time overrun problem, the industry is also facing several problems of poor performance from cost overrun viewpoint. Ahmed et al. (2018) criticised Pakistan's construction sector and asserted that the cost increment tin public construction projects is a ubiquitous problem. Azhar et al. (2008) examined the cost overrun problems in Pakistan and accomplished that almost none of the country's projects finish within the estimated budget, and in many cases, the overrun is up to 60%. Authors listed several causes among those, contract management and tendering practices are the major reasons behind this problem. Haseeb et al. (2011) and Nawaz et al. (2013) also worked out the cost overrun problems in the industry and claimed

that among several other reasons, the contractor is a key player responsible for cost overrun in projects which reaches to more than 60% in some cases. These studies highlighted that poor site management capability, poor communications, poor financial status, lacking in latest technology usage, etc., are the key causes of cost overrun in Pakistan due to the contractors. Moreover, Khan and Khan (2015) surveyed several public projects in Pakistan, and found that around 50% projects were suffered with time, and cost overrun along with poor quality concerns.

The construction sector of Pakistan is also poorly recognised worldwide from a quality standpoint. Khan et al. (2019) performed an insight analysis and criticised the quality in construction projects. Research observed several associated problems in projects, for instance, less experienced and less educated personnel are usually hired at site. The authors reaffirm that contractors' performance in the industry is very poor and not aligned with the quality management system. They found that almost 50% of projects are battered with quality issues. Abas et al. (2015) emphasised on the quality issues that Pakistan construction projects are yet struggling in terms of quality. Sohu et al. (2018) worked out adverse effects of quality in construction projects in Pakistan and found that apart from other problems, contractor related problems including the contract award practices are responsible for this problem in the industry. Memon et al. (2011) also pointed out that quality in a construction project is very poor, and the country is looking for positive changes for a long time. They pointed out further that owing to this construction projects require frequent remedial works. The remedial works in several cases turn into contractual claims and litigation further.

Aforementioned statistics on Pakistan construction sector suggest that one of the major hurdles and problems in the tendering process is the right and capable contractor selection. Kog et al. (2014) believed that the selection of a contractor is one of the challenging decisions in the tendering process. Apart from other objectives, the client evaluates contractor based on several criteria other than bid price to ensure the capability of a contractor for the project and further limit the bidders at a later stage. However, on an account of several characteristics among contractors, the clients are now more conscious of selecting more capable and

suitable from a large number of bidders (Liu et al., 2015). Jaskowski et al. (2010) also believed that to ensure selection of a capable contractor, a client requires more cautious assessment nowadays. Keeping in view the proper assessment, contractor evaluation criteria have been explored by various researchers in the past. However, the most suspicious aspect is whether the criteria set by different authors are appropriate for undertaking complex public projects. In the past, several studies are based on a weak foundation in terms of assessment criteria, and the concept of extensive criteria is still unexplored. Moreover, the criteria investigated for a particular project may not be useful for other countries with dissimilar social, economic, and political environments. This is also witnessed from past studies that criteria differ from project to project (Afshar et al., 2017), and vary according to country and project type (Hosny et al., 2013). Further, the proper weightage to those criteria needs further investigation, for example, how much the contractor's financial position is worthwhile compared to its experience related to the project or vice versa? Moreover, the suitability of those criteria concerning the local surrounding is also imperative. Apart from this, another challenge for the client is to collect the right data from the contractors. This is because in many cases the correct data is not provided by the contractor during the evaluation process and the client has no other way to believe on the documents or past certificates and appreciation awards by previous clients.

In this regard, Skitmore (2002) reported that contractors' right information is challenging to collect in many cases. Birjandi et al. (2019) pointed out that Decision Makers (DMs) confront the issue of appropriate assessment owing to some vague criteria, and reliable information from contractors on criteria is problematic to collect. Wondimu et al. (2020) also confirmed that the contractor manipulates the information on specific criteria and presents the information according to their own advantages. Studies believe that the contractors mislead the clients, and they have no option but to believe them. This happens while evaluation criteria are not suitable for the local surroundings and replicated from other countries‘ advance models. In developed countries, the information may be easily collected but the problem of developing countries like Pakistan is inverse, many times it is very difficult to fetch the right data. Thus, there is more need to work out on these suitable criteria that can be easily evaluated based on the availability of data.

In continuation with the right assessment, another major point for the research interest is that, during the initial scrutiny of contractors (technical assessment stage), clients set the weightage/marks as a threshold value to either qualify or disqualify the contractors, and all qualified contractors are considered equal. A contractor with the highest attained marks in the technical stage does not offer any advantage, and the process terminates there, and the final award is again centred on the minimum offered bid. This contemporary process is based on a discontinuous progression that partially recognises the prominence of the technical phase. Even at the threshold, all qualified contractors would stand in the same queue competing for contract award, which does injustice with the highest-ranked contractors, as also highlighted by (Krishna Rao et al., 2018). However, this part has not been widely addressed, and the decision models overlap with a similar discontinuous assessment concept. This needs further investigation in terms of continuous benefits to contractors with the highest marks.

The aforementioned interrogations are the few problems of this area that needs further investigation on this topic. To cope with the discussed issues, a decision support model (DSM) is required to mould the process into more straightforward and more manageable system. To develop a DSM for contractor selection, initially, it entails input in the form of decision criteria. In literature, several authors worked on selection criteria and agreed on a few criteria for contractor selection such as; experience and past performance personnel capability, financial soundness, safety, equipment capability, quality, the reputation of firm, current backlog and workload, relationships, technology, organisational structure, local geographical information, time and cost overruns in past projects, questions/answer sessions and accessibility to sub-contractors. However, none of the studies has gone beyond these primary criteria.

These selection criteria has utmost importance on the success and failure of construction projects. The careful consideration of such criteria based on competencies, experiences and attitudes can therefore reduce cost escalation (Wardani et al., 2006) and time overruns (Assaf and Al-Hejji, 2006). Furthermore, it can improve quality (Yasamis et al., 2010), environmental performance (Shen and

Tam, 2002), work environment (Yean et al., 2009), and innovation (Manley, 2008). Omran et al. (2012) investigated that the delays in project completion time and increases in construction projects' cost have been closely related to contractors' qualification. Alzahrani and Emsley (2013) investigated that contractor's selection attributes are closely linked to the performance of the project. Memon et al. (2017) linked the safety criteria of contractor selection with project performance in Pakistan. According to Bangash (2016), the selection criteria has close link with project performance, and found that around 30% projects are battered with project failure in terms of time overrun in Pakistan. Moreover, Haseeb et al. (2011) relates contractor's selection criteria such as planning, experience, and management capabilities with project performance in Pakistan. Azhar et al. (2008) found that improvement in contractor selection practices can enhance the chances of successful project in Pakistan. Further, Nawaz et al. (2013) found that project success in Pakistan in terms of cost related issues is significantly concerned with contractor selection criteria such as management capabilities, financial status, and technology usages.

Above discussion on selection criteria and their impact on success and failure in Pakistan construction industry supports the idea of careful selection of criteria for contractor selection. However, several DSM on final contractor selection are proposed based on dissimilar criteria and Multi-Criteria Decision Making (MCDM) techniques to provide the solutions for the above-discussed contractor's issues in the tendering process. Nonetheless, those models are either too complex in terms of data input, with complicated subjective, oriented on few criteria or impractical (Semaan and Salem, 2017). Holt (2010) criticised the advanced model and stated that none of the models have been applied in the public sector due to recent complexity in models. Several studies have developed decision making models and systems to overcome the problem of capable contractor selection by considering the technical and financial bids. For instance, a model developed by Zhao et al. (2020), but regrettably, the study deliberated quite a few model criteria for the system on which the selection is somewhat questionable. Several similar cases were found where studies have focused quite a few model criteria such as (Birjandi et al., 2019; Cheng and Li, 2004; Darvish et al., 2009; El-Abbasy et al., 2013; Jr. et al., 2005; Lam and Yu, 2011; Liu et al., 2015; Marcarelli and Nappi, 2019; Watt et al., 2010). A few other single-stage models were proposed by Anagnostopoulos and Vavatsikos

(2006); Semaan and Salem (2017); Vahdani et al. (2013); Wang et al. (2013); Yang et al. (2016), where the bid price is deliberated during the technical assessment which is in contrast to the public sector procurement procedures around the globe. Other decision models were designed without considering the bid price emulating sole quality based selection which is not pertinent in the public sector, for instance, (Bendaña et al., 2008; Hashemi et al., 2018; Nieto-Morote and Ruz-Vila, 2012; Taylan et al., 2017; Tomczak and Jaśkowski, 2018).

In addition to the above discussed systems and models, various other attempts have been made to devise a two-stage models where the earlier phase assesses the technical performance among the competitors, and the later stage accountable for a financial assessment. However, such models are subjected to dissimilar concepts, and researchers are not agreed on a single suitable solution. For instance, a two-stage model by San Cristóbal (2012) which involved a process of final selection based on project completion time and bid price. Likewise, Liu et al. (2017) designed a two-stage system where the final award was based on health, safety, environment (HSE), technology, and bid price basis. Marcarelli and Nappi (2019) developed another two-stage model wherein after the technical qualification assessment, the final award subjects to the least completion time and the lowest bid. Similarly, Zhao et al. (2020) applied efficiency method to initially prequalify the contractors, and later those contractors were allowed to offer any financial bid, and the final award is subject to the consent of DMs centred on the solo bid price. Marović et al. (2021) developed two-stage model but bid price was treated with quality criteria at the same time. Though the concept of two-stage model is not a new; however, the past two-stage models are not based on continuous assessment, and the concept of efficient use of public resources is ignored. The two-stage continuous assessment is different than contemporary two-stage models; as it is based on continuous progression of technical assessment till final selection of contractor.

The aforementioned problems in a plethora of studies regarding model development are an indication that there is still a need for more investigation on the topic and the suitability of the model is needed to check for a different environment. Also, discontinuous assessment does not benefit the highest-ranked contractors, and

this contemporary process partially recognises the prominence of the technical stage in public tendering. This leads to the entry of less efficient contractors, and those offer lowest bid are qualified for the contract, which later leads to severe issues in the project. This triggers the need of two-stage continuous model for assessment of contractors, where technical assessment stage must be continuous till final selection. This two-stage continuous assessment concept would add further value into the system and enhance the chances of more capable contractor's entry. Furthermore, the previous models are developed for different countries having dissimilar environments. To assess the suitability of the model for different environments is another primary concern. Moreover, the discussed models in literature are either limited, biased, or too complicated for analysis. Also, the selection criteria consideration in most of the models is not extensive, especially for today's complex environment and the applicability of those criteria may be different for other countries such as Pakistan, which is still at a developing phase and has different issues.

Pakistan's construction industry is facing overrun of time and cost, defects at early life, and user dissatisfaction; these causes further lead to claims and litigations (Farooqui et al., 2008). Azhar et al. (2008) connected the Pakistan construction industry issues with current tendering practices and mentioned that besides other problems, the contract management and wrong bidding strategies in Pakistan are responsible for cost overrun problems. A study conducted by Farooqui et al. (2008) claimed that in the public sector of Pakistan, the lowest bid award system is most prevailing which is the major reason for poor performance in the country. The study reaffirmed that 82% of clients in Pakistan believe that poor contractors are selected during the tendering procedure in Pakistan. The wrong selection turns in several prevailing issues in construction performance like higher claims, disputes, work delays, higher cost, and a greater number of change orders. Ali et al. (2018) also criticised the current tendering practices in Pakistan and found that the current tendering practices are among the major reasons for variation of cost in public projects.

Khan and Khan (2015) surveyed various public construction projects in Pakistan and examined the consequences of current tendering malpractices. The study found that almost all projects' quality was not fair, 50% of the projects were affected by delays, and the same was battered by budget overrun (i.e., 50%). The aforementioned issues in the Pakistan construction industry, including overrunning time and budget, quality, health and safety, claims, etc., are prevailing. Numerous researches believe that these issues are owing to malpractices of tendering and wrong contractor selection in a public project.

Comparing to private sector tendering, the public sector tendering is more convoluted. Public sector tendering is different from its private counterpart. It is because, the private organisations are more flexible in their process, and usually, they follow their own developed informal procedure. However, the public departments are more accountable to the public, so, they follow more strict procedures. Also, in many countries, public organisations or governed state corporations have to comply with national public procurement laws for tendering works and services. Owing to such reasons, especially the public accountability, the selection of contractor is based on the lowest bid approach in public tendering. The lowest bid approach in public tendering often resulted in higher costs, longer completion time, and low quality (Feldman, 2006). Sultana et al. (2013) stated that contracts awarded in public sector has 12.4% cost overrun and 30.7% time overrun. Therefore, the strategies in public sector tendering apparently looks in the client‘s favour, but it does not meet the best value for money in the long run, comparing to quality based approaches in private sector.

In Pakistan's public sector, besides the lowest bid award system, the human-based assessment is a common practice in the public sector in Pakistan, which often results in vague and implicit decision, and causes several problems compared to an exact mathematical model. The above-discussed situation of the Pakistan construction industry, and particularly the public tendering demonstrates that Pakistan's construction industry entails moving towards healthier means of selecting contractors. Besides, this subject is a matter of concern for the researchers and DMs in Pakistan, and they should focus on this serious issue. Especially, it is of more

alarming for the public sector of Pakistan, which is the largest client in the country (Khan and Khan, 2015).

Keeping in view the recent downfall causes of the construction industry in Pakistan, the tendering process, and contractor selection decisions during the tendering phase are the most imperative research to investigate for the public sector. The fact is, there are none of the similar models available in Pakistan that can extensively cover the current flaws keeping in view the expected client requirements from the contractors. Moreover, the current models are either non-extensive enough, limited in scope, or not suitable to the public sector. Also, the level of complexity in the contemporary models is another interrogation in the real ground, especially in the public sector. Moreover, the concept of two-stage continuous assessment is entirely unique and need of an hour for successful project delivery. Henceforth, the said problems need consideration for the betterment of construction projects.

1.3 Research Questions

Several prominent discussion in connection to the contractor selection is highlighted in the problem statement. Based on critical understanding overviewed in problem statement, following research questions (RQ) are designed for this study as:

i. RQ1: What are appropriate attributes of contractor selection in terms of extensive nature, appropriate classification, explicit nature, and suitability for public projects in Pakistan and what is their significance?
ii. RQ2: How the clients in Pakistan‘s public sector assess the contractors based on current government procedures? What are the major prevailing issues that hinders the project performance in Pakistan? And what are the possible solutions to improve the current flaws in public tendering?
iii. RQ3: What should be the contractor selection attributes‘ weightages? And how the contractors‘ performance can be assessed by clients?
iv. RQ4: How a decision support model can be developed that can help client to assess the contractors for their final selection in Pakistan‘s public projects?

1.4 Research Aim and Objectives

This research work aims to improve contractor‘s assessment system for final contractor selection in Pakistan‘s public sector via a decision support model based on two-stage continuous assessment concept. In this model, the contractor selection appropriate attributes are considered on priority. The appropriate attributes here refer to the specific contractor selection criteria that must be extensive, appropriately classified, explicit in nature, and suitable for public sector in Pakistan. This model is the earliest of its kind in Pakistan, as none of the similar models has yet been assessed in Pakistan's public sector. Not limited to this, the two-stage continuous assessment system developed herein is a novel approach and has not been explored before. This two-stage continuous assessment is a unique concept where each contractor in the system would be assessed continuously beginning from technical assessment stage until final selection. This continuous assessment would add value into the system as it would guarantee the entry of highly capable contractor. The model's main purpose is to assist the clients in taking a right, transparent, unbiased decision at the tendering stage; to achieve this aim, the following objectives are set as under:

i. To compute the significance of appropriate attributes affecting the selection of contractors for Pakistan‘s construction projects.
ii. To assess the contractor‘s selection practices in Pakistan‘s public sector departments and suggest suitable directions to improve the current process.
iii. To compute contractor selection attributes‘ weightages and performance assessment weightages for contractors‘ assessment.
iv. To develop a decision support model for the final selection of contractors in Pakistan.

1.5 Scope of Study

The construction projects are carried out through a tendering process of the project life cycle where clients are supposed to select their construction partners. This selection of contractors is a multi-criteria approach where, besides the project price, several other criteria are also considered. A plethora of past models were developed on contractor selection issues, but there seem a few flaws in past studies due to their limited scope. Firstly, the considered criteria in their models are not extensive to defined contractor‘s capability and performance; also, in many cases, evaluation criteria are not well designed to fetch real data from contractors. A couple of studies do not extend the parameters into sub-divisions, for example, (Chen et al., 2015; Hashemi et al., 2018; Jaskowski et al., 2010; Liu et al., 2015; Marzouk, 2010; San Cristóbal, 2012; Tomczak and Jaśkowski, 2018; Watt et al., 2010; Yang et al., 2016; Zavadskas et al., 2016). Secondly, the contractor's selection is not well covered in terms of combining appropriate evaluation criteria and bid price in the evaluation stage.

Several inadequacies are found in studies like (Taylan et al., 2017; Tomczak and Jaśkowski, 2018; Yang et al., 2016) where a contractor was evaluated only based on multi-criteria; however, the cost was not a decisive criterion which does not apply to many public sector organisations. Apart from this, previous models are limited to a discontinuous assessment of the contractor‘s capabilities where there was limited recognition of technical stage. The single-stage and two-stage models were limited in their applications as continuous assessment systems and bid price were treated as either sole parameters for selection or combined with a few criteria other than technical assessment criteria. In all cases, the technical stage was acted as discontinuous progression and had limited application, and the concept of multi-criteria assessment still acted as bid-centric.

Numerous shortcomings are found in the scope of a few models like those were extremely uncertain and complex such as the study of (Hashemi et al., 2018; Liu et al., 2017) and further involved only three DMs in developing a final model. Tomczak and Jaśkowski (2018) involved only four DMs in deciding the weightage

of criteria in their model. The scope of a research study like El-Abbasy et al. (2013) was quite assorted, they collected data from different regions, i.e., United States, Canada, and the Middle East, adding higher diversity in the outcome. Many other extensive studies are found that covered sufficient parameters and suitable decision technique, but several other limitations are found. In the study by Semaan and Salem (2017), the detailed data analysis is missing in the prequalification phase, and no suitable decision technique is applied, and the criteria weights are directly assigned as per expert views. The model proposed by Hasnain et al. (2017) is limited on only a few case studies, and no generic model is derived. Taylan et al. (2017) presented an extensive model with several parameters, but the study is limited to apply on a ranking of seven contractors and unable to derive a model itself. Yang et al. (2016) do not provide an extensive model and limit the work in a single phase embedding bid price, rather than to suggest the final stage of evaluation. The study of Krishna Rao et al. (2018) was only limited to a specific case; also bid evaluation stage was not justified and supported without any mathematical or other technical validity. Various other models were designed based on two-stage mode; however, their scope was limited, and the core aim of insight assessments of both stages was ignored. Despite the two separate stages, the final selection was based on combined stages ignoring the concept of efficient use of public resources. In other cases, the final award is subjected to the second stage (i.e., financial parameters) ignoring the concept of the value of money and prominence of technical parameters and their role in expected performance in the project. The two-stage continuous assessment model focuses on continuous assessment of contractors from technical stage until the final selection stage. This assessment values the highly capable contractors as the final selection is not only based on bid price but combination of technical assessment and bid price.

This study envisages previous studies' limitations and expands the scope of work accordingly to enhance the knowledge boundary. To achieve the intended goal, the study's scope is limited to the construction industry of Pakistan. There are four provinces in Pakistan, one federal territory and others being the Gilgit, and Azad Kashmir zone. This study, due to limited time and resources highly focused in the province of Sindh. Besides, the other provinces and regions were also covered. It

should be noted that the prime information from the procurement departments, major public sector departments, and registration body is same throughout the country.

Pakistan construction industry is widely divided into major sections, namely the private and the public sector. Also, being a developing country, there is the influence of external agencies which either donate or provide loan for the infrastructure development like World Bank (WB), Asian Development Bank (ABD), Japan International Cooperation Agency (JICA), etc. When these agencies are involved, the projects have to follow the respective guidelines and criteria. In contrast, this research work concentrates on those projects that are fundamentally funded and governed by the government of Pakistan, which is the country's biggest sector. Nevertheless, international and national guidelines, international documents, and criteria are followed and reviewed. In Pakistan's public projects to deal with the tendering and procurements, an independent organisation, namely the Public Procurement Regulatory Authority (PPRA), endowed this kind of work. Besides this organisation, a statuary body called Pakistan Engineering Council (PEC) is held responsible for the registration of contractors and to regulate the laws to be followed by those registered organisations, i.e., contractors. This study is deeply concerned with PPRA and PEC. Their current process, the governing laws, regulations, criteria for contractor‘s selection, and the entire selection process is the part of this work.

Several projects are part of the country like traditional project delivery, design and built, public-private partnership, etc., however; this study focused on the traditional design-bid-build delivery system projects, irrespective of type of project, i.e., buildings, infrastructure, highways etc. Therefore, this study aims to develop a contractor selection model which could be adopted for any type of public project but must be executed as per traditional procurement method. It is prominent to highlight that this study covers the tendering evaluation and selection of contractors based on multi-criteria. The bid evaluation is based on PPRA, and PEC's traditional process with modifications and separate modelling is performed to drive an index. This is done to make this model compatible with the current system, and further to penetrate into the system and being widely applicable in the country.

1.6 Significance of Research

The selection of contractors involves a multi-criteria approach for construction clients that seems a huge problem worldwide. The consequences of wrong selection lead to multiple problems of time, cost, quality, safety, and ultimately the long term serviceability of projects (Chen et al., 2021). The eventual goal of every project owner (i.e., the client) is timely completion of the project with stipulated cost and designed quality with greater satisfaction. The right selection of stakeholders can achieve such outcomes from projects. The nature of the construction industry is already complicated, with many requirements, which further triggers the selection of a capable contractor that can perform well and fulfil the client's desired objective.

Pakistan has immense economic potential and is one of the world's rapidly growing countries with current GDP growth of 5.8% (World Bank, 2018). This high economic growth parallel effects the other industries, including the construction. The recent developments in this field are not unforeseen to anyone after the execution of China Pakistan Economic Corridor (CPEC) and the other recent developments in transportation, water resources, and other infrastructure projects such as motorways, main railway line 1 (ML1), mega dams' construction, and other renewable energy projects. According to a recent annual report of Pakistan's state bank, the construction sector shares the highest foreign direct investment (FDI) of 25.44% in the development of the country (State Bank of Pakistan, 2018a). This can be further witnessed by the GDP growth of the construction sector, which increases by 9.04% in 2017 compared to 2016. The increment in GDP from the construction sector in Pakistan averaged at 239,361.33 Million PKR (from 2006 until 2017), reaching an all-time high of 320,769 Million PKR in 2017 from a record low of 186,380 Million PKR (Pakistani Rupees) in 2006 (State Bank of Pakistan). According to United Nations (2017), Pakistan's GDP from construction increasing rapidly, i.e., 6% in 2014 to 13.1% in 2016. From 2017 to 2018, it has got a massive increment of 9.13% (Pakistan Bureau of Statistics, 2017).

Examining the above facts and figures, it can be witnessed that the Pakistan construction industry's current situation is improving and rapidly moving towards mega-developments. Despite the said facts and figures, the sector is full of crises and thus, not well stabilised yet. Apart from other political and economic concerns, the absence of right technical persons and the incapable contractors constitute a significant hindrance and dragging back this industry (Nawaz and Ikram, 2013). Moreover, the traditional single bid price criteria contractor selection of the country does not justify the industry. Persisting issues of traditional bidding systems lead to advanced methods and efficient decision systems globally. Looking at several advancements in developed countries and the use of decision-making tools worldwide, this is the right time to develop a suitable system to transfer this sector on the right path. In this regard, Pakistan's public sector industry is looking for an extensive DSM to take efficient, unbiased, and transparent timely decisions, therefore, an assessment system is highly beneficial and needs an hour in the country.

To cope with this scorching issue of the Pakistan public construction sector, this study aims to provide an assessment and selection system for the tendering assessment process that clients can utilise to carry out the tendering evaluation successfully. This study is exceedingly expedient for higher authorities in Pakistan like PPRA and PEC to mould and shape up their tendering and contracting policies accordingly. One of the several reasons is that the model preserves the concept of efficient use of public resources which is a primary concern of these agencies in the public sector. Hence, this decision model's major implication in this context is to support; the DMs, higher officials, public sector organisations, and other clients from the construction industry of Pakistan in taking the right decisions and ultimately to improve the contractor selection process in Pakistan. This research would be beneficial for the industrial purposes to utilise the concept for effective decisions on commercial projects; furthermore, it would open the future avenues for the research in academia.

1.7 Outline of Thesis

This thesis is organised into seven chapters. The chapters are organised in a way that research objectives can be achieved smoothly. The description of each chapter is briefed below.

Chapter 1 describes the background of research, problem statement, research questions, aims, and objectives of the study, scope, and significance of work. This chapter is significant to understand the foundation of this study. The background of research supports in understanding the origin of this research in a systematic way and the associated developments in the past in this research realm. The problem statement described the issues in past studies that have not been fully resolved and required further investigations. Based on the problem statement, the research questions, aim and objectives were designed. The scope of work helps in understanding how the scope of the present thesis is enhanced compared to previous work and the associated limitation in the present study. At the end of the chapter, this study's significance is presented.

Chapter 2 covers the literature review to support this study. This chapter structurally describes the public procurement and public tendering process in the beginning. This review's prime purpose is to understand the origin of the contractor selection process that commences from the procurement phase of construction. Therefore, it is essential to understand the procurement process, its stages, and a brief about the tendering and its preparation and related terms and stakeholders' involvement. The chapter explains the associated problems in public tendering and the current public tendering practices around the globe. The contemporary process of the lowest bid award is explained, and its drawbacks in the construction are also highlighted. This chapter also overviewed the Pakistan construction industry and the public tendering process. The prevailing issues in Pakistan are also highlighted. The most prevalent issues of the public sector in Pakistan are highlighted and linked with the public tendering. The last section of this chapter covers public tendering practices as per PEC and PPRA regulations. Therefore, this chapter forms the basis of this

study and helps in designing a novel model keeping in view the current scenario of the Pakistan public sector.

Chapter 3 presents the most relevant literature on the topic of this thesis. This chapter underlines the multi-criteria selection of contractors in detail. The importance of multi-criteria selection is explained to understand the current advancement in public tendering. Exhaustive literature is provided on contractor selection attributes and the associated paradox in the past studies. The unique formulation of attributes is also briefed. This chapter comprehensively discusses the MCDM techniques employed in past relevant studies, their pros, and cons. This leads to the selection of MACBETH and SMART methods for this study, and the preliminaries of these methods are explained in detail alongside their applications. The last part of this chapter includes a critical discussion on the contemporary designed models and the bid evaluation models. This discussion is imperative to apprehend what has been done in those models and how the present study is novel.

Chapter 4 outlines the research methodology of this study. In this regards, data collection and analysis processes are explained in details. The data collection process is described in detail, such as public department visits, interactive sessions, and expert surveys. The process of each method is presented in this chapter. Furthermore, the analysis process of various methods used in this study are explained.

Chapter 5 is designed to represent data analysis and discussion. Step by step analysis of data collection with two individual questionnaire surveys is presented in this chapter. The data analysis is described with respect to the study objectives. In the beginning, the most influential attributes of contractor selection are presented and discussed. Secondly, the results on the present condition of public tendering in Pakistan and their directions are highlighted. The last part of this chapter presents the process of calculating the attributes‘ weightages in M-MACBETH software. The process of sensitivity analysis is also briefed.

Chapter 6 explains the model development process. In this chapter, the process of weightages distribution, i.e., performance assessment weightages are computed with the SMART technique's aid. Furthermore, the integration of MACBETH-SMART helps in computing the attributes‘ weightages and their distribution. The process of contractors‘ assessment system is also elaborated. This chapter highlights the model stages where the first-stage entails the technical assessment explained with MACBETH-SMART integration. The second-stage of financial assessment is also explained with the help of developed mathematical formulas. In the end, the process of validation of the model is highlighted.

Chapter 7 elucidates research findings, conclusion and recommendations. Furthermore, knowledge contribution, novelty of research, limitation and further research are explained in this chapter.

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LIST OF PUBLICATIONS

Journal with Impact Factor

1. **Khoso, A.R**., Md Yusof, A., Khahro, S.H., Abidin, N.I.A.B., Memon, N.A. (2021). Automated Two-stage continuous decision support model using exploratory factor analysis-MACBETH-SMART: an application of contractor selection in public sector constructions. *Journal of Ambient Intelligence and Humanized Computing*. https://doi.org/10.1007/s12652-021-03186-w **(Q1, IF: 4.596)**
2. **Khoso**, **A. R.,** Yusof, A. M., Song-Chen, Z., Skibniewski, M. J., Chin, K. S., Khahro, S. H., Sohu, S. (2021). Comprehensive Analysis of State-of-the-Art Contractor Selection Models in Construction Environment-A Critical Review and Future Call. *Socio Economic Planning Sciences*. https://doi.org/10.1016/j.seps.2021.101137 **(Q1, IF: 4.923)**
3. **Khoso**, **A.R.,** Yusof, A. M., Song-Chen, Z, Xian-Jia, W., Skibniewski, M.J., Memon, N. A. (2021). "Embedded Remote Group Environment through Modification in MACBETH- An application of Contractor's Selection in Construction", *Journal of Civil Engineering & Management*, 27(8), 595-616. 10.3846/jcem.2021.15763 **(Q2, IF: 2.957)**
4. **Khoso, A. R.,** & Md Yusof, A. (2020). Extended Review on Contractor Selection in Construction Projects. *Canadian Journal of Civil Engineering*, 47(7), 771–789. https://doi.org/10.1139/cjce-2019-0258. **(Q4, IF: 0.895)**

Indexed Journal

5. **Khoso, A. R**., Yusof, A. M., Chai, C. and Laghari, M. A. (2021) "Robust Contractor Evaluation Criteria Classification For Modern Technology Public Construction Projects', *Journal of Public Procurement*, 21(1), pp. 53–74. https://doi.org/10.1108/JOPP-06-2020-0053 **(Indexed by SCOPUS & WEB OF SCIENCE)**

6. **Khoso, A. R.,** Yusof, M. A., Leghari, M. A., Siddiqui, F., & Sohu, S. (2021). Public Tendering Practices, Issues and Directions - A Case of Pakistan Construction Sector. *Pertanika Journal of Science and Technology*, *29*(1), 123–147. https://doi.org/10.47836/pjst.29.1.07. **(Indexed by SCOPUS & WEB OF SCIENCE)**

7. **Khoso, A. R.,** Yusof, M. A., Abidin, N. I. A. B., & Memon, N. A. (2021). Technical Evaluation of Contractor in Public Tendering- A Comparative View-Point of Stakeholders. *International Journal of Project Organisation and Management*, *XX*(X), XXX–XXX. **(Indexed by SCOPUS) (Published Online).**