

**A/E SELECTION MODEL BASED ON A/E
QUALIFICATIONS AND PROJECT CONSTRAINTS**

BY

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DEDICATION

After 20 years of having the dream of graduating from King Fahd University of Petroleum and Minerals, I would like to dedicate this thesis to my first inspiration, who guided me with his wisdom and patience from the day I refused to continue my higher education right after high school until today, where I have achieved my second master's degree. To my model, my father, Engineer Salih Alajairi. To my mother Mona, my sincerest appreciation for all the care, love, prayers, and support you have given me. "My Lord! Bestow on them the Mercy even as they cherished me in childhood."

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LIST OF ABBREVIATIONS

A/E: Architectural Engineer

CP: Commercial Practices

CQS: Selection Based on Consultant's Qualifications

EC: Evaluation Committee

FBS: Selection under a Fixed Budget

FIDIC: Fédération Internationale des Ingénieurs Conseils (International Federation of Consulting Engineers)

FTP: Full Technical Proposal

HOQ: House of Quality

HSE: Health, Safety, and Environment

KPI: Key Performance Indicator

LCS: Least-Cost Selection

LOI: Letter of Invitation

PBS: Prince Based Selection

PMC: Project Management Consultant

QBS: Quality-Based Selection

QCBS: Quality- and Cost-Based Selection

QFD: Quality-Function-Deployment

RFP: Request for Proposals

SSS: Sole Source Selection

STP: Simplified Technical Proposal

TOR: Terms of Reference

VOC: Voice of Customer

DEFINITIONS

To provide a clear overview with a common understanding, the following terms are defined.

- **Architect Engineer (A/E):** This is the firm responsible for designing, defining specifications, preparing the bill of quantity, and the full project package that will be handed over to the client for bidding purposes. Also, he will be responsible for the supervision and approval of construction activities.
- **Engineering Services:** This is defined as professional services that are related to design, development, construction, or repair of a real property as well as incidental services for members of these professions. The services include revisions, investigations, surveys, evaluations, consultations, supervision, planning, conceptual designs, plans and specifications, cost estimates, inspections, and other related services.
- **A/E Services:** This refers to services of a professional nature provided by the A/E using their skills to study, design, organize, and manage projects; they advise the Borrowers and, when required, build their capacity. A/E offer Borrowers the possibility of a more effective and efficient allocation of their resources by providing specialized services for limited amounts of time without any obligation of permanent employment.
- **Quality-Based Selection (QBS):** Quality-Based Selection is based on the evaluation of the proposal quality without any initial consideration for the cost.
- **Quality Function Deployment:** This is an evaluation and selection model that prioritizes customers' requirements toward producing a competitive quality product or service in the design phase by using a series of matrices and other techniques.
- **Price-Based Selection (PBS):** Price-Based Selection is based on the evaluation of the proposal quality without any initial consideration for quality.

- **Client:** The stakeholders who have both control and responsibility for cost and income related to a project.
- **Contractor:** The party responsible for implementing and performing the construction work, including the provision of labor and materials, in accordance with the plans and specifications and under a contract specifying the cost and schedule for completion of the work.
- **Criteria:** Criteria is the list of attributes defining how a project's constraints will be achieved.
- **Voice of Customer:** This is a term that describes the customer's feedback about his experience and expectations in order to improve services that are focused on customer requirements, expectations, understanding, and improvement of deliverables.
- **Project Constraints:** These are conditions or tasks that must be completed to ensure the success or completion of a project.
- **Quality:** Quality is the "fitness for purpose". This definition emphasizes the two components of quality that are critical to managing any project: features that meet customer needs and freedom from failures.
- **Time:** Time refers to a schedule that is analyzed and developed for the completion of a project or deliverable.
- **Cost:** Cost meant the total funds needed to complete the project.

All the below definitions are explained in relation to the A/E.

- **Quality Performance:** The quality of standards, management, design, specifications, and assurance required to meet a project's constraints.
- **Technical Experience:** This means the skills and knowledge as well as years of experience.
- **Past Performance:** The success rate of services in previously completed projects.

- **Project Management:** This is planning, organizing, and managing efforts in order to reach the project constraints.
- **Customer Satisfaction:** This is the degree of achieved customer expectations with the provided services.
- **Key Personnel:** Key Personnel are the project managers responsible for the planning and execution of a project.
- **Staffing:** This is the number of qualified personnel in the firm.
- **Cost Control:** Cost Control is the ability to manage the project expenses within a specified budget.
- **Price:** The A/E services fees.
- **Project Context:** This is the degree of familiarity of the environment in which a project operates based on experience with similar projects.
- **HSE:** The ability to define Health, Safety, and Environment principles and apply best practices during the project.
- **Financial Standing:** The financial stability of a firm to accommodate any payment delay and prevent any bankruptcy during project period.
- **Firm Capacity:** The ability of a firm to handle many projects at one time.
- **Reputation:** The image of the firm in the market.
- **Project Type:** The category of the construction project type that the firm worked with, such as residential, institutional, industrial, highway, and heavy construction.
- **Resources:** This is the availability of staff, software, equipment, offices, etc.
- **Economical Design:** The design that meets the customer's quality expectations at the lowest cost.

- **Problem Solving:** Rapidly providing solutions for unexpected issues to make the project run smoothly.
- **Service Time:** The period that an A/E requires to complete the design package.
- **Current Workload:** The number of projects that the firm is currently handling.
- **Design Accuracy:** The highest design quality with minimum design mistakes and defects.
- **Estimation Accuracy:** The highest quality of estimating the required quantity and price.
- **Specialization:** The types of services that A/E specializes in, such as architectural, civil, mechanical, electrical, and project management.
- **Design Constructability:** This is the degree of build ability to which the designed plan facilitates its construction and utilization.
- **Office Location:** The geographical location of a firm.
- **Risk Management:** The process used to manage uncertain conditions that might affect the project constraints.
- **Design Change Flexibility:** Design Change Flexibility can allow construction to evolve over time as the user's needs change.
- **Design Regulation:** Familiarity with the rules of design to comply with conditions, standards, and regulations.
- **Failed Projects:** The number of projects that were not delivered as required and expected.
- **Project Location:** The geographical location of the construction site.
- **Firm Stability:** The issues that may cause a firm to stop operating during the project period. This includes disputes with other customers, government violations, etc.
- **References:** The list of customers that can share a firm's performance on their projects.

- **Bid Quality:** The clarity and quality of preparing technical and commercial bidding proposals as per the project requirements.
- **Pre-qualification Ability:** This means assisting the owner in evaluating contractors and suppliers.
- **Project Engagement:** The level of concern that a firm is willing to be awarded for the project.

ABSTRACT

Full Name : Feras Salih Ajairi
Thesis Title : A/E Selection Model Based On A/E Qualifications and Project Constraints
Major Field : Construction Engineering and Management
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Properly selecting an Architectural or Engineer office to provide designing and engineering services is fundamental toward achieving a successful project within the required level of project constraints (quality, time, and cost). Improper selection of an architect engineer may lead to project failure, poor project quality, or exceeding the project schedule and budget. In general, the designing and engineering services are procured based on the lowest price or largest office size. The objectives of this research are to study the architect engineer selection practices for designing services in the large industrial sectors in Saudi Arabia; to study the different selection systems to procure architect engineer services; to study the selection criteria that are used to measure architect engineer performance; and to develop a model to assist the project owner in selecting an architect engineer based on the required level of quality, time, and cost constraints. The required data were collected through a developed structured questionnaire from private owners who build industrial projects. The research revealed that 72% of large industrial project owners need to improve their architect engineer selection process to achieve the required level of quality, time, and cost. The research identified a list of potential criteria to measure architect engineer performance. The criteria were evaluated based on importance and influence on project constraints and found that only two criteria out of the top ranked were used in the owner's current system. Moreover, it was possible to develop a reliable and validated Quality Function Deployment model to assist owners of industrial projects in properly selecting an architect engineer.

ملخص الرسالة

الاسم الكامل: فراس بن صالح بن عبدالله العجيري

عنوان الرسالة: اختيار المكاتب الاستشارية بناءً على مؤهلات المكتب الاستشاري والقيود الثلاثية

التخصص: هندسة وإدارة البناء

تاريخ الدرجة العلمية: رمضان ١٤٤١هـ

تعتبر عملية اختيار المهندس المعماري لتقديم خدمات التصميم والخدمات الهندسية مفتاح نجاح المشروع بناءً على مستوى القيود المطلوبة والتي تشمل مستوى جودة المشروع و وقت تنفيذه وتكلفته الإجمالية. قد يؤدي الاختيار غير المناسب للمكتب الاستشاري إلى فشل المشروع والتي قد تتضمن مستوى جودة أقل من المطلوب أو تجاوز الجدول الزمني أو تجاوز ميزانية المشروع. إن عملية اختيار خدمات المكتب الاستشاري لا تتم عن طريق اختيار السعر الأرخص أو حجم المكتب، بل تتم عن طريق اختيار مقدم الخدمة الذي سيقدم أفضل الخدمات نحو نجاح المشروع.

يتضمن هذا البحث العلمي دراسة ممارسات المنشآت الصناعية في المملكة العربية السعودية لتقييم واختيار المكاتب الاستشارية لتنفيذ المشاريع الخاصة بهم. كما سيقدم هذا البحث دراسة المعايير المستخدمة من قبل المنشآت الصناعية للاختيار وتقييم مستوى المكاتب الاستشارية.

إن الهدف الرئيسي من هذا البحث العلمي هو تقديم نموذج لأصحاب المشاريع وذلك بناءً على متطلبات وقيود المشروع التي يشترطها مالك المشروع. كما سيتضمن هذا البحث دراسة وتقييم أهم المعايير لقياس أداء المكاتب الاستشارية. إضافة إلى ذلك، سيتم دراسة تأثير كل معيار من معايير قياس أداء الاستشاري على قيود المشروع والتي تشمل جودته و مدته وتكلفته. لقد تضمنت دراسات هذا البحث العملي بأن نسبة ٧٢% من المنشآت الصناعية الكبرى تحتاج

إلى تطوير عملية اختيار المكتب الإستشاري لتحقيق مستوى الجودة والتكلفة والمدة المرجوة من مالك المشروع. كما قدم البحث العلمي قائمة من المعايير ليتم دراستها بناء على أهميتها لتقييم مستوى مقدم الخدمة وربطها بأهداف وقيود المشروع. ومما توصلت له الدراسة، بأن أغلب المنشآت الكبرى تستخدم معيارين فقط من أهم معايير تقييم الأداء.

بعد تلك الدراسات، سيقوم البحث بتقديم نموذج لاختيار المكتب الاستشاري الأنسب للمشروع وذلك بربط أداء المكتب الاستشاري مع قيود المشروع باستخدام دالة نشر الجودة (QFD). ومن ثم، سيتم تطبيق النموذج الجديد على أصحاب المنشآت الصناعية لمقارنة نتائج إختيار المكتب الاستشاري بواسطة النموذج الجديد بالمقارنة مع النموذج الحالي المتبع من قبل مالك المشروع وذلك للتحقق من نتائج النموذج الجديد.

تاريخ الدرجة العلمية: رمضان ١٤٤١هـ

CHAPTER 1: INTRODUCTION

There are many types of construction project delivery systems, but there are four delivery systems that are the most dominant, namely design-bid-build, design-build, construction management, and construction management at risk. Under the design-build delivery system, the contractor retains the service of an architect engineer (hereafter referred to as the A/E), and the owner has the least influence on the design quality and specifications. In order to reduce the risk in the procurement method, owners proceed with design-build to shift the risk to the contractor through a single point of responsibility (Cheung et al., 2001). With a design-bid-build delivery system, the owner retains the service of an A/E to prepare the complete design package for construction bidding. Design-bid-build has a separate scope for design, which is mainly awarded to separate A/E designing offices that will be responsible for completing the whole design package. In this type, the owner has the maximum influence in defining the required level of quality and specification. The quality of the A/E service is the initial key for meeting a project's constraints. The risk of the constructed quality level lies with the responsibility of the owner, where the contractor implements the specifications and design as per the bidding documents. In order to achieve the owner's desired level of satisfaction, the owner needs to select the most suitable A/E to minimize the risk of poor quality design, project delay, costly projects, budget overrun, and a high number of claims, among other issues.

The main purpose of this research is to assist the owner in selecting the most appropriate A/E based on fulfilling the project constraints in relation to the A/E selection criteria. Moreover, to develop a selection model to evaluate A/E performance to meet the project constraints.

1. STATEMENT OF PROBLEM

Project constraint optimizations are intended to complete the construction process on time, cost, and desired quality. Owners use different systems, including sole source selection, best value selection, quality-based selection (QBS), price-based selection (PBS), alternative delivery options, fixed price/best technical value, weighted criteria, and more for selecting A/Es that will prepare the bidding documents for their projects. However, the majority of projects suffer from delays caused by the project documents. Based on a statistical study, 70% of projects evaluated experienced a time overrun (Assaf & Al-Hejji, 2006), where the quality of the A/E services was one of the major sources of project delay. Assaf et al. (1995) indicated that design errors caused by designers were ranked as the second factor among the list of factors causing project delays in large projects in Saudi Arabia. In the same line, the authors cited the building code used in the design, approval of shop drawings, and poor experience as the other main sources of project delays caused by A/E's poor technical experience. Insufficient communication between the owner and the A/E during the designing phase was another major cause of project delay due to poor project management skills.

It seems that the current A/E selection systems are not effective in choosing the desired qualified A/E to provide the proper services to the owner. It is believed that the selection of an A/E based solely on A/E capability criteria are not effective due to the lack of connection with the project constraints. This research aims to assist owners in selecting the most suitable A/E. The A/E selection criteria needs to be identified in relation to the project constraints and evaluated based on the order of importance to fully assess the performance of an A/E. Moreover, a selection model needs to be developed to assist owners in the A/E selection process.

2. RESEARCH QUESTIONS

1. How does an owner purchase A/E services?
2. How does an owner evaluate A/Es?
3. What are the owner's project constraints?
4. What are the most important A/E selection criteria?
5. What is the degree of influence of the selection criteria on the project constraints?
6. How can an owner select the most appropriate A/E?
7. What is the best tool to use in the A/E selection process?

3. STUDY OBJECTIVES

The main objective of this study is to develop an architecture or engineering office selection system based on qualification criteria and project constraints for owners in Saudi Arabia to select the best A/E office to develop design packages for the owner's industrial projects. The objectives are specifically are:

1. To determine the current A/E selection systems that owners in Saudi Arabia use to select A/E offices for developing design packages for industrial projects.
2. To determine the owners' selection criteria.
3. To determine the project constraints.
4. To measure the importance of the qualification criteria to measure A/E performance.
5. To measure the influence of the qualification criteria on the project constraints.

6. To develop an architecture or engineering office selection system based on the qualification criteria and project constraints for owners in Saudi Arabia to select the best A/E office to develop design packages for the owner's industrial projects.

4. SIGNIFICANCE OF THE STUDY

The results of the research will assist owners and scholars in understanding the existing process of selecting, procuring, and evaluating A/Es. In addition, this research will assist the project owners to select the most proper A/E that will satisfy their project constraints. The contributions of this research study can be summarized as follows.

1. The research study can be a fruitful reference for owners and researchers to understand the existing market procurement method, selection criteria, and evaluation process for selecting an A/E.
2. This project will assist project owners in understanding the weaknesses in their current selection and procurement processes.
3. Identifying the A/E selection criteria based on importance in relation to the influence on the project constraints will be a benefit of this research.
4. This study will help owners in their A/E selection process through the development of a selection model.

The selection of the proper and most qualified A/E will reduce the possibilities of design errors that can cost the owners time and funds and delay the project.

To the best knowledge of the author, this study is the first in linking the qualification criteria to the project constraints in the selection of an A/E office. Therefore, this study adds value to the book of knowledge in construction and A/E selection.

5. SCOPE AND LIMITATIONS

This study will be limited to the selection systems that are used to select A/E offices to develop engineering design packages. This study is also limited to large industrial owners who mostly build industrial projects and who are located, due to time and cost constraints, in the Eastern Province of Saudi Arabia.

6. THESIS ORGANIZATION

This thesis is organized as follows. Chapter 1 covers the statement of the problem, research questions, study objectives, significance of the study, and scope and limitations. Chapter 2 covers the introduction of the literature review and previous studies. Chapter 3 covers the research methodology and the required data, data collection, population and sample size, and data analysis. Chapter 4 presents the results and discussion, including the importance of and relevance of the data in order to proceed with the study to reach the desired conclusion. Chapter 5 reaches the summary, findings, conclusions, and recommendations of this research and makes recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

This chapter studies the different extant research approaches to uncover the underlying assumptions related to assisting owners in their selection of the most suitable A/E for their project. This includes previous studies in selection systems to uncover the effects of procurement methods on the A/E selection process. Moreover, previous studies on A/E selection criteria are reviewed to understand different approaches on selection criteria in relation to the owner's project constraints. This will assist in studying the utmost significant criteria to measure A/E performance.

1. A/E SELECTION SYSTEMS

Babatunde et al. (2012) defined the procurement method as “as the management of the total process involved in construction project delivery”. Assaf et al. (2017) emphasized the importance of proper A/E selection due to its significant effect on project quality, time, and cost constraints. To reduce the risk in the procurement method, owners proceed with the design-build method to shift the risk to the contractor through a single point of responsibility (Cheung et al., 2001). “The emphasis of procurement methods is on optimizing all parameters involved in project delivery namely, time, cost and quality” (Babatunde et al., 2012). The procurement process is risky, as the bidders take the maximum profit at the minimum risk (Babatunde et al., 2012). Therefore, it will be required to pre-qualify A/Es before inviting them to the bidding process. Moreover, there will be a need to filter the number of poor bidders to reduce the procurement risk. Boer et al. (2001) defined the steps of a process to filter the number of suppliers as, “The first step always consists of defining and determining the set of acceptable suppliers while possible subsequent steps serve to reduce the number of suppliers to consider.

Basically therefore, pre-qualification is sorting process rather than a ranking process. However, the subtle yet important difference between sorting and ranking is often not explicitly made in the (purchasing) literature”. Multiple factors need to be considered in selecting an appropriate A/E for a project with a quantitative systematic approach. Such an approach is required in order to achieve the project’s required level of quality, time, and cost (Assaf et al., 2017).

The project constraints need to be identified to assure the proper procurement of A/E services. Chinowsky and Kingsley (2009) stated about the procurement system in federal governmental projects, “It is to be the policy of the Federal Government to publicly announce all requirements for architectural and engineering services, and to negotiate contracts for architectural and engineering services on the basis of demonstrated competence and qualification for the type of professional services required and at fair and reasonable prices.”

Bowen (1999) stated that “Once client objectives have been established, a fundamental aspect of the procurement process which requires early attention is the selection of the most appropriate organizational structure (procurement system) for the design and construction of the project ... The way in which many clients and their professional advisors select the method of building procurement can be haphazard, ill-timed and lacking in logic. It has also been established that one of the principal reasons for the poor performance of the construction industry is the inappropriateness of the choice of procurement system.”

Thus, understanding the different procurement methods is required in order to assure the proper A/E purchasing. Previous studies will be reviewed on the following procurement methods:

1. Sole Source Selection
2. Best Value Selection
3. Quality-based Selection (QBS)
4. Price-based Selection (PBS)

5. Alternative Delivery Options
6. Fixed Price/Best Technical Value
7. Weighted Criteria

1.1 SOLE SOURCE SELECTION

Sole source selection was explained by Chinowsky and Kingsley (2009) as having a contract with a single firm for a certain period of time where the firm will perform the designing and engineering works for a certain cost. The issue will be if there are a high number of projects where the consultant can control the work up to a certain load and agreeing on the cost for a high number of projects. Sole source selection includes the selection of a design build team based on selection criteria like technical experience, past performance, and relationship in the previous project. In the design building delivery system, there is an opportunity to select the team of a bidder with the lowest price. The owner will therefore lose the competitiveness price factor opportunity in the public sector (Wardani et al., 2006). Sole source selection is not a common procurement method in the public sector, however, where the bidders need to have equal completion opportunity (Molenaar & Gransberg, 2001). The sole source selection system is mainly used in justified circumstances, such as if the project schedule constraint is short, like in emergency reconstruction or if there are limited qualified designers (Molenaar & Gransberg, 2001).

2. BEST VALUE SELECTION

The best value selection is where the bidder responds to the project owner with a proposal that is primarily evaluated based on the technical aspects that fit with the project's associated costs. After receiving the bidder's proposal, the owner may negotiate with the bidder after evaluating

which proposals have the best value for the owner. By using this method, the owner will weigh each specific factor in addition the project size and type. There will be a prequalification of the bidders based on technical criteria before the final selection. After the technical evaluation, the owner will procure services from the bidder who will provide the best value to the owner (Wardani et al., 2006).

2.1 QUALITY-BASED SELECTION (QBS)

QBS is a procumbent method for purchasing a service that focuses on the quality of the deliverables. QBS is essential in meeting the project constraints on time, cost, and quality (Chinowsky & Kingsley, 2009). The key benefits of using QBS are ensuring cost effectiveness, lowering the risk of complex projects, experiencing better projects with owner satisfaction, accounting of emerging societal issues, encouraging innovation to protect intellectual property, and supporting owner capacity building (Chinowsky & Kingsley, 2009). Wardani et al. (2006) stated that the owner will select a firm based on his qualifications in certain required criteria, such as technical experience, past performance, reputation, competences, and financial stability. The owner will request a list of qualifications and will select the most qualified firm based on qualifications first within a fair and reasonable price. Also, they stated that the procurement method will be considered quality-based if the non-cost criteria are more than 50% in the evaluation system. Owners prefer to select firms with whom they have a longtime relation in business and whom they have a clear overview of their qualifications. Christodoulou et al. (2004) stated that an A/E should be selected based on qualifications rather than the most competitive and lowest price. Patients should not select doctors based on the lowest price, and lawyers should not be selected based on the lowest hourly rate. All of these jobs should be treated the same by

getting the service from the most qualified in their field. It is clear that A/Es should be selected based on qualifications where the servicing cost is minor in comparison to the project's total cost and the qualified A/E's ability to increase the probability of project success.

2.2 PRICE-BASED SELECTION (PBS)

Wardani et al. (2006) defined price-based selection as selecting a firm for construction services based on the project value and related cost. By using this evaluation system, if the selection criteria that are related to the cost items are more than 90%, it will be considered a low bid selection and procurement system. The price of the bidder is considered a major competitiveness factor in the selection process.

Christodoulou et al. (2004) stated that in most competitive bidding, there are usually two packages submitted separately that include the technical package, which contains the technical proposal, and the commercial package, which shows the price. When the owner receives both packages, he could determine if he is interested in going forward with selecting the most qualified based on the technical proposal or to select the lower price bidder. The firm will evaluate the firm and will assure that the bidder will cover the minimum required scope of work in the technical proposal. If the owner sees that the bidder covered the scope of work, then he selects the lowest price bidder. This is considered price-based selection. When owners review the technical package and focus on the qualifications of the firm that will provide the best service, this is considered quality-based selection. Christodoulou et al. (2004) also stated that selecting a quality-based A/E instead of the lowest price will provide a significant project cost savings. Owners measuring the competitiveness based on price are thinking about why they should pay more for a service that could cost less. This cost savings in the design phase could, however, lead

to an increase in the number of change orders, litigation, operation cost, and additional costs during the project and maintenance phases. Moreover, the project scope is not defined properly in the conceptual stage of the project and thus the cost proposal from an A/E firm is not similar in scope and will lead to change orders or disputes. While it is unwise to pay too much, it could be worse to pay too little. In order for an A/E to cover the designing cost, they will hire a lower quality designing staff to keep costs down, making the A/E incapable of achieving the project's required goals, which will affect the owner in the long run. Selection based on price might be applicable for construction contractors but not for design services. Design services have very small room for deviation compared to construction. A qualified A/E will provide services that will lead to project success; however, the competitive bidding process is time consuming and has hidden costs that will mask all the cost savings (Christodoulou et al., 2004).

Alofi (2015) stated that a committee member at the Ministry of Finance will review all the bids. If the bidder price is higher than the market price, they will have two options. The first option is to negotiate with the bidder who has the lowest cost to reduce their bid to be closer to the market price. If the lowest bidder refuses to reduce the price, then they will negotiate with the second lowest bidder. If the committee does not find a bidder who is within their price range, then they will remove a scope item that will not affect the project in the future in order to lower the price. The minimum number of bidders that need to be within the project budget is three. The recommended bidder is to be selected after an evaluation of the technical quotation. This procurement method is price-based, but it is slightly better compared to the lowest price-based method, in that a better quality bidder could be selected.

Price-based selection (PBS) will result in insufficient fees for the consultant to provide a quality service, which will lead to a reduction in the overall project value (FIDIC, 2011). Moreover, the consultant will reduce the services and quality to lower the consultation fees if the

client's major selection criteria is the lowest price. This will lead to a lower service quality, which will then lead to no innovation in technical, management, and project delivery. The additional services to be reduced are of a conservative design with a higher cost for construction, inadequate documentation, less consideration of alternative design, reduced pre-design investigation, services outsourcing, and minimal consideration of project life cycle cost (FIDIC, 2011). Other factors include loss of capacity building, increase in construction and operation cost, time extension in the construction phase, and potential risks and damages (FIDIC, 2011). When the price is the main selection factor, the project scope's quality is reduced. The Florida Senate Committee on Governmental Operations called the selection of consultants based on price "penny-wise and pound-foolish". This is because savings from the consultant price are insignificant when compared to the associated costs of compiling a detailed scope of work, soliciting bids, evaluating proposals, and reducing the quality of service.

2.3 ALTERNATIVE DELIVERY OPTIONS

The procurement method is a critical process that organizes the overall framework of the responsibilities and authorities in the construction process. To minimize the risk of having a proper selection system, the project owner might have another delivery system in order to shift the risk to the contractor, such as having a design-build delivery system (Cheung et al., 2001). Chinowsky and Kingsley (2009) stated that since a quality-based system is not a delivery system, the owner prefers to select an alternative delivery system, such as design-build or Construction Management at Risk (CMR), to shift the risk to the contractor.

Mahdi and Alreshaid (2005) described CMR as selection where the contractor will be hired to construct the project and they agree to take the risk to complete the project within the agreed

cost. Construction Management is another alternative delivery option, where the CMR delivery system is similar to the traditional selection system except that the owner will hire the CMR to take the risk during the design phase.

2.4 FIXED PRICE/BEST TECHNICAL VALUE

Molenaar and Gransberg (2001) stated that fixed price/best technical value is a competitive method to select a firm not just by the price. The fixed price/best technical value is mainly used with a design bid build delivery system. Many sectors, especially in the public sector select a bidder between qualifications and price-based selection. The fixed price/best technical value selection system is in between the price- and quality-based systems (Molenaar & Gransberg, 2001). This system has two ends where the fixed price sealed bidding is on one side and sole source selection is on the other. There are two methods that include one-step or two-step methods. Figure 1 shows the range between the fixed price and sole source procurement methods. The selection of the firm between the two ends is considered as fixed price/best technical where the selection is a combination between the price and the quality, not just the lowest price. In step one, the evaluation is done for the technical package in addition to the price to determine the best value where it is mainly used in the public sector. In step two, there are more considerations for the quality, which is mainly used in the private sector and is considered a weighted criteria.

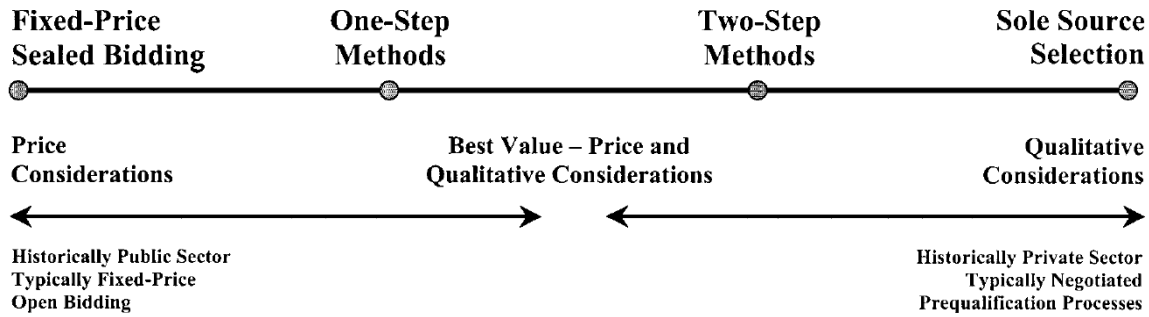


Figure 1. Procurement Methods Range

2.5 WEIGHTED CRITERIA

The weighted criteria are defined as a set of non-price criteria that could be used a procurement tool to evaluate the bidders' offers and which lead to delivery of the monetary value and project constraints. The appropriate selection criteria must be designated to review the bidders' offers. The best value of money that leads to the project constraints needs to be selected.

Napier (1990) stated that the two-step process shown in Figure 1 is to make a prequalification of the bidder before in order to have a short list. Then, the short list of prequalified bidders will submit their technical and commercial packages. The project will then be awarded to the bidder with the best value. Molenaar and Gransberg (2001) defined weighted criteria as combining the technical and commercial proposal in the evaluation and comparison matrix. This will define the rate for each criterion in the matrix, which will define its value.

3. SELECTION CRITERIA

Al-Besher (1998) discussed the client ranking list for selecting a designing office. The client criteria for selection are the list of projects completed by the A/E firm; professional experience,

training, and education of the key personnel; the size and form of the A/E firm's organization; experience; availability of resources; capacity to complete the work; compatibility; design capability; experience in work of similar size; type and complexity; specialization; office location of the firm; and professional standing. The criteria are important for consultant selection, but it needs to be linked to the project constraints.

Kasma (1987) discussed the process of selecting the designing firm. The selection starts with soliciting the qualifications of firms, which will introduce the project quality requirements, budget, and time limitations. Then, conduct an explanatory meeting to present detailed information about the project. After that, the designing office's proposal will be received by the owner. Next, the owner will select the firms to interview, where the selection criteria will be technical experience, past performance, staffing, project approach, and consultant location. The problem with this process is that it is subjective and lacks a clear linkage between the criteria with project constraints.

The World Bank (2006) explained in detail the selection process for consultant offices. The process of selection consists of 20 steps. The process is very detailed with a high level of accuracy, where the process reviews both technical and commercial proposals. It also measures the consultants' interest level in the project. The problem with this process is that it is very time consuming and requires preparing deeply detailed documents from the owner and consultant sides. Also, the process requires frequent face-to-face meetings.

VDOT (2016) explained the process used for selecting designing firms in the State of Virginia. The Department of Transportation uses their own software in order to evaluate the consulting offices. The main criteria for evaluation are management, prosecution and progress, quality of work, and cooperation/coordination. Under each of these main criteria are sub criteria used to measure the consulting firm's performance. The process is more suitable for preparing

contracts but not to measure the required performance of the consulting along with the project constraints.

ACEC (2006) discussed the process of selecting a consultant in the State of Oklahoma. The selection process involves multiple phases, which are selection of the most qualified engineer, definition of the scope of service, and fee and contract negotiation. The process will be done in three stages. Stage one is evaluating the statements of qualifications of designing engineer. The second stage is an evaluation of the designing engineer with references from previous clients. The last stage is an evaluation interview of consultants with listed criterion after having a short list. The process is well set up, and they have their own formatting for it. There is a need to have more criteria for evaluation with a link to the project goals.

Ling (2003) discussed a conceptual model for selecting project managers. The model consists of four factors, and each one has its classified criteria for evaluation and measuring the performance of A/Es. The factors are task performance, contextual performance, network, and price. Each factor will focus only on the tender of the designer with detailed measure. This appear clearly when the concept measures the price factor. The price factor focuses on the consultant fees and to allow delay payment but there is no reference about the project overall price overrun.

Assaf, Jannadi, Siddiqui, and Al-Besher (1998) explained the model for selecting A/Es in Saudi Arabia. The model will list criteria for selection and then to apply Analytic Hierarchy Process (AHP) for selecting an A/E. AHP is a sufficient tool to identify how the project could succeed, but it does not indicate what is required to make the project successful.

Ng and Skitmore (1999) discussed the pre-qualification criteria of both the client and consultant for the selection of a contractor. Consultant input is significant for the selection of the most qualified criteria, which will lower the risk of hiring a poor contract. The criteria are very

useful for the selection of consultants, but the study didn't discuss the prequalifications for the consultant selection.

Tufte (1988) discussed the optimization uses of consulting offices for governmental and public projects. The study identified the criteria and the implementation of the contractual process for hiring a consulting office, some of which apply to evaluations for consultant selection. Other criteria include compensation, responsibility, and communication, which are contractual criteria that explain how the consultant is going to do his work. Preparing the contract is the last step for hiring a consultant, but the common criteria for contractual selection will be correct for the research.

Ng and Chow (2004) explained the consultant preselection process before inviting a designing firm to submit their technical and commercial proposal. The study identified the common criteria for preselection of a consultant and classified the criteria into four groups: technical capabilities, management capabilities, financial capabilities, and quality attitude. The client can evaluate the criteria to choose the most appropriate designing firm. The evaluation process will require scoring the criteria for the consultant before bidding as the initial stage. This will be helpful in minimizing the number of consultation firms for the study, but the most important part is missing, namely selecting and hiring the best fitting consultant for the job.

Al-Hussain and Agha (2007) explored the most important criteria for the selection of consulting offices. The significance of their research is that the criteria was linked and grouped to the project constraints based on quality, time, and cost. The study did rank for the most important criteria from the owner's perspective, and it shows that the top twelve criteria are quality criteria. Accuracy of cost estimation was ranked as thirteen, accuracy of early cost estimation as twenty-six, and the financial control of the project was thirty-three. The research

made a recommendation that, “Further studies could be conducted on the methods required to improve overall consultant performance”.

Ng, Kumaraswamy, and Chow (2001) examined the selection of consultants based on both commercial and technical assessments. They clarified that the selection of consultant based on price alone is problematic and might cause project delays and project cost overrun. They discussed the implementation of the Combined Technical and Fee Assessment Approach (CTFA). The method consists of a pre-qualification stage, short listing stage, and final selection stage. The final selection stage evaluates both the technical and fee proposals. The researchers used the weighted criteria selection method, which will test the value of technical proposal against the price. The problem with this process that it focuses on the value of the proposal fee to the technical proposal, where it is supposed to focus on the quality of the project deliverables.

Chow and Ng (2007) used the fuzzy gap analysis model to evaluate the performance of consulting engineers in order to select the office with the highest performance. The study listed the selection criteria to make an evaluation and compares the client expectations to the service quality of the A/E. This is an excellent method for evaluating what the requirements (client expectation) are on how to reach the client requirements (A/E performance).

Basham (1983) asserted that a consultant needs to be first evaluated based on selection criteria, and then the price is the next step. This clarifies that the quality of a consultant is more important than the price, but the client’s expectations regarding the quality of deliverables remains the most important aspect.

Ling (2002) did research on the selection of design-build contractors based on the designer’s performance. The evaluation in this respect will be on the hard and soft attributes of the designer. The hard attributes, for example, are job knowledge, proficiency of tasks, and experience. The soft attributes include social skills, project control, and commitment. The model is based on the

optimum multiple regression performance prediction model. The designer is the dependent variable, whereas the client's most important attributes are the independent variables. The model is very useful in measuring consultants' performance, as they are the main keys of project quality. It is important to keep the client's quality expectations connected to the project as well.

Cheung, Kuen, and Skitmore (2002) developed a model for evaluating consulting offices. The software used in this model consists of seven main criteria, specifically a set of grouped attributes. The main criteria are firm background, past experience, technical resources, management capabilities, financial stability, quality assurance, and innovation capability. Each designing firm will be evaluated based on their performance, and the highest score means the consultant has the highest performance.

Atout (2016) identified the main factors that cause consultant delays in a project. The highest five ranking factors are discrepancies of contract documents, incomplete drawings, design management, inquiry response, and approval for construction drawings. The consulting firms need to measure and assure a level of readiness to avoid delays caused by their firm. Also, threats causing delays need to be identified so they can be minimized.

Hattan and Lalani (1997) developed a selection project idea for consulting engineers for public projects in the state of California. The selection process is a quality-based selection using a comprehensive manual called *Quality Based Selection: A Guide for the Selection of Professional Consultant Services for Public Owners*. The selection process consists of three main stages, which are the interviewing stage, identifying the selection criteria, and the final interview for selection. The process links the criteria to the project constraints, but it is slightly complicated because there are three steps to the evaluation process.

The government of Tasmania (2018) determined that consultants are to be selected based on professional competence, qualification, expertise, managerial ability, resources, project

approach, and service quality. After that, there is a set of defined criteria that the consultant will be evaluated on. This method also measures the consultant's performance without linking them to the project constraints.

CIC (2014) discussed the process of selecting consultants in Hong Kong. Their process consists of seven main criteria divided into sets of attributes. The main criteria are consultant general criteria, concept and planning, design development, construction drawings, tender, construction, and commissioning and handover. The weakness appears to be in the linkage between the attributes and the project goal.

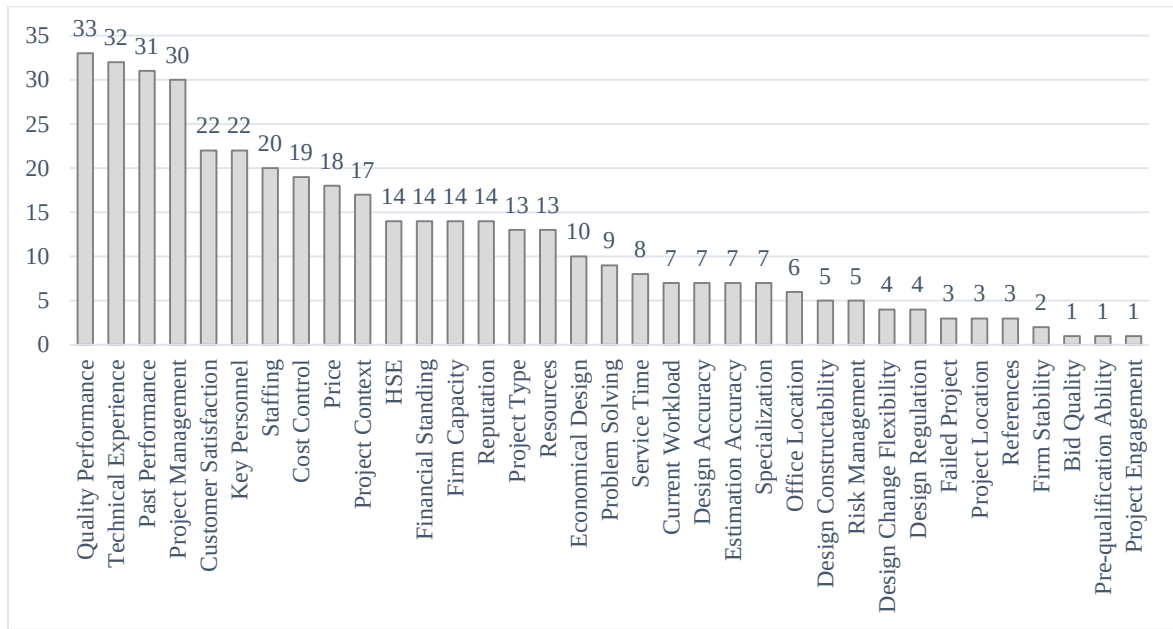
Mihailovic, Birmanecic, and Obradovic (2014) explained consultant selection in the agro-sector. Their selection process is quality-based and includes a proper process for measuring the consultant's performance. In agro projects, innovation creativity is a main criteria that is not included in construction projects.

Martinovic and Delibasic (2014) also identified consultant selection factors. There are four main factors that identify the quality of consultants who will work on ERP projects. These factors are cost, work experience, educational level (which depends on occupational seminar), and communication ability. The occupational seminar is not a factor to be measured for construction consultants.

Sporrong (2011) applied their research to the Swedish municipality's procurement process. Mainly in the public sector, the focus on price for the selection process is in conflict with client quality requirements. Their study shows that municipal projects focus on price or the easy non-price criteria when selecting a consultant. Also, the survey used in this study showed that personal information is the main source for procurement decisions, which make the selection personal. The source of information is an important criterion on which to measure a consultant's past performance, but it is not the only one.

Ha, Hoai, and Lee (2015) detailed a selection process for Project Management Consultant (PMC) based on QBS by using Fuzzy Analytical Hierarchy Process (FAHP). The process consists of three levels. Level one is the specified goal for PMC selection. Level two is the five main criteria for the selection, which includes past experience, financial stability, resources, technical solution, and tender prices. Level three is the attributes under the main criteria group, which will measure the consultant's performance. If level one was replaced with the project constraints, this would make the selection process a complete and proper selection.

El-Sayegh (2009) structured a selection model for selecting construction management at risk. The model consists of five main process, namely the strategic alignment, selection criteria, initial screening, firm's evaluation, and sensitivity analysis. In the strategic alignment, the project goals are identified to request a proposal from an interested firm. In the selection criteria process, criteria hierarchy are developed based on the criteria priority with a link to the project goals. The initial screening includes a review of the submitted proposals to develop a short list. Next, the firms will be evaluated and their score calculated. Finally, a sensitivity analysis will rank all the firms and select the top-ranked firms. This methodology is an excellent tool for evaluating the performance of the consultants alongside the project goals. Table 1 shows a list of the selection criteria and the number of times they are mentioned in the papers. The criteria are identified differently in various papers, so the researcher uses common wording for each criterion. The criteria versus the number of times they are mentioned is listed below in Figure 2.



Note: The criteria rankings based on the mentioned times with resources are listed in Table 1.

Figure 2. Criteria vs. Mentioned Times

TABLE 1. Summarized Criteria Table

SR	Criteria	Mentioned times	Mentioned by
1	Quality Performance	33	(Al-Besher, 1998), (Ng, 2001), (El-Sawalhi, Eaton, & Rustom, 2007), (Doloi, 2009), (Ahmed & Kangari, 1995), (Chan, Ho, & Tam, 2001), (Nguyen, Ogunlana, & Lan, 2004), (Collins & Baccarini, 2004), (Wang & Huang, 2006), (Gransberg & Barton, 2007), (Ahadzie, Proverbs, & Olomolaiye, 2008), (Doloi, 2009), (Toor & Ogunlana, 2010), (Alzahrani & Emsley, 2013), (VDOT 2016), (ACEC 2006), (Ling 2003), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Ng & Skitmore, 1999), (Ng & Chow, 2004), (Al-Hussain & Agha, 2007), (Chow & Ng 2007), (Ling 2002), (Cheung, Kuen, & Skitmore 2002), (Atout & 2016), (Government of Tasmania 2018), (CIC 2014), (Ling, Ofori, & Low 2003), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015), (Assaf et al., 2017)
2	Technical Experience	32	(Kasma, 1987), (Al-Besher, 1998), (Russell, Hancher, & Skibniewski, 1992), (Holt, Olomolaiye, & Harris, 1994), (Alsugair, 1999), (Wong, Holt, & Cooper, 2000), (El-Sawalhi, Eaton, & Rustom, 2007), (Watt, Kayis, & Willey, 2010), (Xia, Skitmore, & Zuo, 2012), (Gransberg & Barton, 2007), (Doloi, 2009), (Alzahrani & Emsley, 2013), (ACEC 2006), (Ling 2003), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Tufte, 1988), (Ng & Chow, 2004), (Al-Hussain & Agha, 2007), (Basham 1983), (Ling 2002), (Cheung, Kuen, & Skitmore 2002), (Atout & 2016), (Hattan & Lalani 1997), (Government of Tasmania 2018), (CIC 2014), (Ling, Ofori, & Low, 2003), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015), (El-Sayegh 2009) , (Assaf et al., 2017)
3	Past Performance	31	(Kasma, 1987), (Al-Besher, 1998), (Jafari, 2013), (Russell, Hancher, & Skibniewski, 1992), (Holt, Olomolaiye, & Harris, 1994), (Ng, 2001), (Singh & Tiong, 2006), (Doloi, 2009), (Watt, Kayis, & Willey, 2010), (Xia, Skitmore, & Zuo, 2012), (Cooke-Davies, 2002), (Collins & Baccarini, 2004), (Wang & Huang, 2006), (Doloi, 2009), (Toor & Ogunlana, 2010), (Alzahrani & Emsley, 2013), (VDOT 2016), (ACEC 2006), (Ling 2003), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Ng & Skitmore, 1999), (Ng & Chow, 2004), (Basham 1983), (Cheung, Kuen, & Skitmore

SR	Criteria	Mentioned times	Mentioned by
			2002), (Hattan & Lalani 1997), (Government of Tasmania 2018), (Ng, Kumaraswamy, & Chow 2001), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015), (El-Sayegh 2009) , (Assaf et al., 2017)
4	Project Management	30	(Russell, Hancher, & Skibniewski, 1992), (Holt, Olomolaiye, & Harris, 1994), (El-Sawalhi, Eaton, & Rustom, 2007), (Doloi, 2009), (Sodangi & Amran, 2011), (Ahmed & Kangari, 1995), (Cooke-Davies, 2002), (Nguyen, Ogunlana, & Lan, 2004), (Collins & Baccarini, 2004), (Wang & Huang, 2006), (Gransberg & Barton, 2007), (Alzahrani & Emsley, 2013), (VDOT 2016), (ACEC 2006), (Ling 2003), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Ng & Skitmore, 1999), (Ng & Chow, 2004), (Al-Hussain & Agha, 2007), (Ling 2002), (Cheung, Kuen, & Skitmore 2002), (Atout & 2016), (Hattan & Lalani 1997), (Government of Tasmania 2018), (CIC 2014), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015) , (Assaf et al., 2017)
5	Customer Satisfaction	22	(Jennings & Holt, 1998), (Watt, Kayis, & Willey, 2010), (Xia, Skitmore, & Zuo, 2012), (Chan, Ho, & Tam, 2001), (Nguyen, Ogunlana, & Lan, 2004), (Collins & Baccarini, 2004), (Wang & Huang, 2006), (Ahadzie, Proverbs, & Olomolaiye, 2008), (Toor & Ogunlana, 2010), (Ling 2003), (Ng & Skitmore, 1999), (Al-Hussain & Agha, 2007), (Chow & Ng 2007), (CIC 2014), (Mihailovic, Birmancevic, & Obradovic 2014), (Ling, Ofori, & Low 2003), (Sporrong 2011), (Chow & Ng 2003), (El-Sayegh 2009)
6	Key Personnel	22	(Al-Besher, 1998), (Watt, Kayis, & Willey, 2010), (Xia, Skitmore, & Zuo, 2012), (ACEC 2006), (Ling 2003), (Tufte, 1988), (Ng & Chow, 2004), (Al-Hussain & Agha, 2007), (Basham 1983), (Ling 2002), (Cheung, Kuen, & Skitmore 2002), (Atout & 2016), (Hattan & Lalani 1997), (Government of Tasmania 2018), (CIC 2014), (Mihailovic, Birmancevic, & Obradovic 2014), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015), (El-Sayegh 2009) , (Assaf et al., 2017)

SR	Criteria	Mentioned times	Mentioned by
7	Staffing	20	(Kasma, 1987), (Al-Besher, 1998), (Wong, Holt, & Cooper, 2000), (Doloi, 2009), (Chan, Ho, & Tam, 2001), (Collins & Baccarini, 2004), (ACEC 2006), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Ng & Chow, 2004), (Cheung, Kuen, & Skitmore 2002), (Atout & 2016), (Hattan & Lalani 1997), (Government of Tasmania 2018), (CIC 2014), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015) , (Assaf et al., 2017)
8	Cost Control	19	(ACEC 2006), (Ling 2003), (Cheung, Kuen, & Skitmore 2002), (CIC 2014), (Ng, Kumaraswamy, & Chow 2001), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003) , (Assaf et al., 2017)
9	Price	18	(Al-Besher, 1998), (Jennings & Holt, 1998), (Alsugair, 1999), (Sodangi & Amran, 2011), (Ahmed & Kangari, 1995), (Collins & Baccarini, 2004), (Wang & Huang, 2006), (Gransberg & Barton, 2007), (Ahadzie, Proverbs, & Olomolaiye, 2008), (Doloi, 2009), (Toor & Ogunlana, 2010), (Ling 2003), (Mihailovic, Birmancevic, & Obradovic 2014), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Ha, Hoai, & Lee 2015), (El-Sayegh 2009) , (Assaf et al., 2017)
10	Project Context	17	(Kasma, 1987), (Al-Besher, 1998), (Xia, Skitmore, & Zuo, 2012), (ACEC 2006), (Ling 2003), (Tuftte, 1988), (Chow & Ng 2007), (Ling 2002), (Cheung, Kuen, & Skitmore 2002), (Hattan & Lalani 1997), (Government of Tasmania 2018), (CIC 2014), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015), (Assaf et al., 2017)
11	HSE	14	(Ng, 2001), (El-Sawalhi, Eaton, & Rustom, 2007), (Xia, Skitmore, & Zuo, 2012), (Collins & Baccarini, 2004), (Ahadzie, Proverbs, & Olomolaiye, 2008), (Doloi, 2009), (Toor & Ogunlana, 2010), (Alzahrani & Emsley, 2013), (Ng & Skitmore, 1999), (Al-Hussain & Agha, 2007), (Government of Tasmania 2018), (Sporrong 2011), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015)
12	Financial Standing	14	(Russell, Hancher, & Skibniewski, 1992), (Ng, 2001), (Singh & Tiong, 2006), (El-Sawalhi, Eaton, & Rustom, 2007), (Sodangi & Amran, 2011), (Alzahrani & Emsley, 2013), (Ling 2003), (Ng & Skitmore, 1999), (Ng & Chow, 2004), (Hattan & Lalani 1997), (Ha, Hoai, & Lee 2015), (El-Sayegh 2009), (Assaf et

SR	Criteria	Mentioned times	Mentioned by
			al., 2017)
13	Firm Capacity	14	(Al-Besher, 1998), (Russell, Hancher, & Skibniewski, 1992), (Wong, Holt, & Cooper, 2000), (Doloi, 2009), (Watt, Kayis, & Willey, 2010), (Sodangi & Amran, 2011), (Xia, Skitmore, & Zuo, 2012), (VDOT 2016), (ACEC 2006), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Ng & Skitmore, 1999), (Basham 1983), (Mihailovic, Birmanecvic, & Obradovic 2014), (Assaf et al., 2017)
14	Reputation	14	(Kasma, 1987), (Jennings & Holt, 1998), (Alsugair, 1999), (Ng, 2001), (Watt, Kayis, & Willey, 2010), (Ahmed & Kangari, 1995), (Ling 2003), (Ng & Skitmore, 1999), (Cheung, Kuen, & Skitmore 2002), (Mihailovic, Birmanecvic, & Obradovic 2014), (Ling, Ofori, & Low, 2003), (Chow & Ng 2003), (El-Sayegh 2009), (Assaf et al., 2017)
15	Project Type	13	(Al-Besher, 1998), (Holt, Olomolaiye, & Harris, 1994), (Sodangi & Amran, 2011), (Doloi, 2009), (ACEC 2006), (Ling 2003), (Ng & Skitmore, 1999), (Ng & Chow, 2004), (Ling 2002), (Ling, Ofori, & Low 2003), (Ng, Kumaraswamy, & Chow 2001), (Ha, Hoai, & Lee 2015), (Assaf et al., 2017)
16	Resources	13	(Al-Besher, 1998), (Wong, Holt, & Cooper, 2000), (Toor & Ogunlana, 2010), (Alzahrani & Emsley, 2013), (ACEC 2006), (Ng & Chow, 2004), (Mihailovic, Birmanecvic, & Obradovic, 2014), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003), (El-Sayegh 2009), (Assaf et al., 2017)
17	Economical Design	10	(Ling 2003), (Tufte, 1988), (Chow & Ng 2007), (Ling 2002), (Hattan & Lalani 1997), (Government of Tasmania 2018), (CIC 2014), (Ling, Ofori, & Low 2003), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011)
18	Problem Solving	9	(Al-Besher, 1998), (Watt, Kayis, & Willey, 2010), (Ling 2003), (Ling 2002), (CIC 2014), (Ling, Ofori, & Low 2003), (Sporrong 2011), (Chow & Ng 2003), (Ha, Hoai, & Lee 2015)
19	Service Time	8	(Ahadzie, Proverbs, & Olomolaiye, 2008), (Toor & Ogunlana, 2010), (Cheung, Kuen, & Skitmore 2002), (Government of Tasmania 2018), (CIC 2014), (El-Sayegh 2009), (Assaf et al., 2017)

SR	Criteria	Mentioned times	Mentioned by
20	Current Workload	7	(Holt, Olomolaiye, & Harris, 1994), (Ling 2003), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Ling 2002), (Cheung, Kuen, & Skitmore 2002), (Ling, Ofori, & Low 2003), (Assaf et al., 2017)
21	Design Accuracy	7	(Ling 2002), (CIC 2014), (Ling, Ofori, & Low 2003), (Sporrong 2011), (Chow & Ng 2003), (Assaf et al., 2017)
22	Estimation Accuracy	7	(Al-Hussain & Agha, 2007), (Chow & Ng 2007), (Ling, Ofori, & Low 2003), (Ng, Kumaraswamy, & Chow 2001), (Sporrong 2011), (Chow & Ng 2003), (Assaf et al., 2017)
23	Specialization	7	(Al-Besher, 1998), (Jennings & Holt, 1998), (El-Sayegh, 2009), (Ng & Chow, 2004), (Government of Tasmania 2018), (El-Sayegh 2009), (Assaf et al., 2017)
24	Design Constructability	5	(Ling 2003), (Chow & Ng 2007), (Ling 2002), (Cheung, Kuen, & Skitmore 2002), (Ling, Ofori, & Low 2003)
25	Office Location	6	(Kasma, 1987), (Al-Besher, 1998), (Alsugair, 1999), (Wong, Holt, & Cooper, 2000), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Assaf et al., 2017)
26	Risk Management	5	(Doloi, 2009), (Chan, Ho, & Tam, 2001), (Collins & Baccarini, 2004), (Ahadzie, Proverbs, & Olomolaiye, 2008), (ACEC 2006)
27	Design Change Flexibility	4	(Doloi, 2009), (Ling 2003), (Atout & 2016), (CIC 2014)
28	Design Regulation	4	(Ling 2003), (Ling 2002), (Atout & 2016), (CIC 2014)
29	Failed Project	3	(Russell, Hancher, & Skibniewski, 1992), (Ng, 2001), (Ng & Skitmore, 1999)
30	Project Location	3	(Wong, Holt, & Cooper, 2000), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Chow & Ng 2003)
31	Firm Stability	2	(Ng, 2001), (Al-Hussain & Agha, 2007)
32	References	3	(Al-Besher, 1998), (Assaf, Jannadi, Siddiqui, & Al-Besher, 1998), (Assaf et al., 2017)
33	Bid Quality	1	(El-Sayegh, 2009)
34	Pre-qualification Ability	1	(Wong, Holt, & Cooper, 2000)
35	Project Engagement	1	(Ling 2003)

CHAPTER 3: RESEARCH METHODOLOGY

This chapter presents the steps taken to achieve the objectives set for this study. The required data, data collection, population and sample size, and data analysis are presented in the following sections.

1. REQUIRED DATA

The objective of this study mandates the availability and collection of the following three different data sets:

1. Current Owner A/E selection system.
2. Evaluate the degree of importance of each selection criteria to select an A/E.
3. Evaluate the degree of influence of the selection criteria on each project constraint.

1.1 CURRENT OWNER A/E SELECTION SYSTEM

1.1.1 OWNER SELECTION SYSTEM

The first set is related to the current systems for selecting an A/E for preparing bid packages for industrial projects. This system will be required to collect data on the types of A/E selection systems used in the market. The literature review revealed several A/E selection systems. The potential systems are:

1. Sole Source Selection
2. Best Value Selection
3. Quality-based Selection (QBS)
4. Price-based Selection (PBS)

5. Alternative Delivery Options
6. Fixed Price/Best Technical Value
7. Weighted Criteria

1.1.2 OWNER A/E SELECTION CRITERIA The second set is related to the A/E qualification criteria, which projects owners use whenever they select A/Es to prepare bid packages for their projects. The following criteria were collected from various sources of the literature and have been identified to be required as a potential list of A/E qualification criteria: Quality Performance

2. Technical Experience
3. Past Performance
4. Project Management
5. Customer Satisfaction
6. Key Personnel
7. Staffing
8. Cost Control
9. Price
10. Project Context
11. HSE
12. Financial Standing
13. Firm Capacity
14. Reputation
15. Project Type
16. Resources
17. Economical Design

18. Problem Solving
19. Service Time
20. Current Workload
21. Design Accuracy
22. Estimation Accuracy
23. Specialization
24. Design Constructability
25. Office Location
26. Risk Management
27. Design Change Flexibility
28. Design Regulation
29. Failed Project
30. Project Location
31. Firm Stability
32. References
33. Bid Quality
34. Pre-qualification Ability
35. Project Engagement

1.1.3 PROJECT CONSTRAINTS The third set is the project constraints, which includes all variables that owners set for their projects, including quality, time, and cost. Project constraints as stated are conditions or tasks that must be completed to ensure the success or completion of the project. Quality is "fitness for purpose", which emphasizes the two components of quality that are critical to managing any project: features that meet customer needs and freedom from failures. Time refers to a schedule that is analyzed and

developed for the completion of a project or deliverable. Cost is the total funds needed to complete the project.

1.2 EVALUATE THE DEGREE OF IMPORTANCE OF EACH SELECTION

CRITERIA IN ORDER TO SELECT A/E

The purpose of the survey is to identify a weight for the importance of the selection criteria (IHi) that will be used by the owners when implementing the evaluation QFD model. The survey will evaluate the importance of each A/E selection criteria that is a required characteristic of meeting the project constraints. The surveyor's results will identify the value for the weight of the importance of the selection criteria (IHi), which will be used in the QFD data matrix.

1.3 EVALUATE THE DEGREE OF INFLUENCE OF SELECTION CRITERIA ON

EACH PROJECT CONSTRAINT:

The purpose of the survey is to identify a weight for the influence of the selection criteria (IHi) that will be used by the owners when implementing the evaluation QFD model. The survey will evaluate the influence of each A/E selection criteria that is a required characteristic for meeting the project constraints. The surveyor's results will identify the value for the weight of the influence of the selection criteria (IHi), which will be used in the QFD data matrix.

2. DATA COLLECTION

The required data were collected through a developed structured questionnaire from the top management of owners' organizations which procure engineering services for industrial projects. The questionnaire consists of five sections. The first section contains questions seeking information on respondents' characteristics, such as job title, level of education, years of experience, number of years with current employer, and role in A/E selection process. The second section contains questions seeking information on the characteristics of the respondent's organization, such as organization type, line of business, size, average A/E contract design value, and annual average project size. The third section seeks information on the owner's current A/E selection system. This section will check if the owner has a prepared list of potential A/E offices to be invited for bidding. Also, it will collect information about the general criteria used by the owner to select an A/E, such as the A/E design specialization, type of project to be designed, past performance with the owner, etc., along with data about the type of selection system that is used to procure A/E services, such as price-based system, quality-based system, weighted criteria, etc. Furthermore, the third section will also collect data about the selection criteria used in the owner's current system, which will include data about the effectiveness of the owner's current system, level of satisfaction, and if the current system meets the project constraints. The fourth section consists of questions seeking information on the degree of importance of each selection criteria in order to select an A/E that will meet the project constraints. The fifth section seeks information on the degree of influence of selection criteria on each project constraint.

2.1 TOOLS FOR DATA COLLECTION

The tools used for research data collection were:

1. Web Survey: The web survey was used to collect data on the following:
 - a. Current A/E selection process used by private owners in the eastern province of Saudi Arabia,
 - b. Importance of A/E selection criteria, and
 - c. Influence of selection criteria on project constraints.
2. Interviews, Teleconference, and Video Conference Tools: These tools were used with the private owners in the eastern province of Saudi Arabia who accepted to contribute to the research on A/E selection models.

2.2 POPULATION AND SAMPLE SIZE

The study is limited to the large industrial sector and companies with more than 250 employees in the eastern region of Saudi Arabia. The General Authority for Statistics (2018) in Saudi Arabia reported that there is a total of 635 large industrial sectors in Saudi Arabia, 153 of which are located in the eastern province. Figure 3 presents the distribution of the industrial organizations in the Eastern Province based on their sizes as measured by the number of employees.

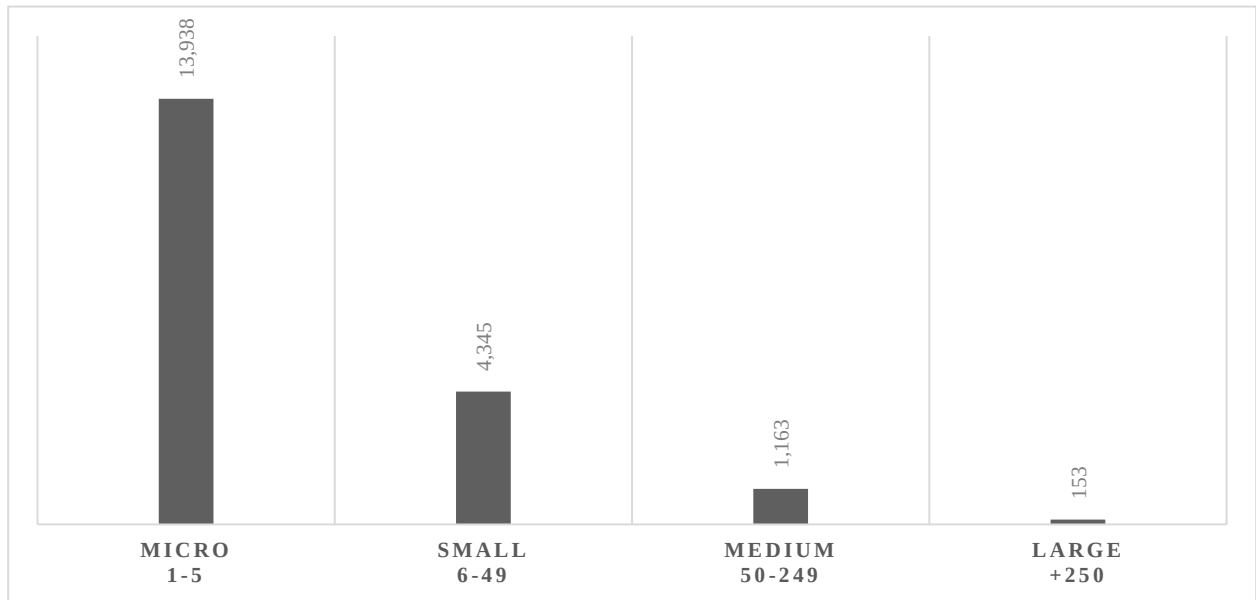


Figure 3. Number of Industrial Establishment by Size in Easter Region of Saudi Arabia

To estimate the required sample size, the Kish equation will be applied, as shown in equation 6:

$$n = \frac{p*q}{SEM^2 * (1 + \frac{n_0}{N})} \quad (6)$$

$$n_0 = \frac{p*q}{SEM^2} \quad (7)$$

Where:

n_0 = Initial estimated sample size

n = Final estimated sample size

p = Probability of picking response (50% max for the research)

q = (1-p)

SEM=Max allowed standard error (10% for the research)

N= Targeted population size

First, the initial estimated sample size needs to be determined as calculated below:

$$n_o = \frac{50\% * 50\%}{10\%^2} = 25$$

Then, the final sample size can be determined as calculated below:

$$n = \frac{50\% * 50\%}{10\%^2 * (1 + \frac{25}{635})} = 25.98 \approx 26$$

The final sample size required for the research is twenty-six large industrial sectors to collect the survey for the questionnaires. Table 2 provides an overview of the sample size calculations and the number of industrial establishments in the eastern province out of the total population in Saudi Arabia.

TABLE 2. Number of Industrial Establishment & Sample Size Out of Total Population

Administrative Area	Micro	Small	Medium	Large
	1–5	6–49	50–249	+250
Eastern Region	13,938	4,345	1,163	153
Total Population in Saudi Arabia	87,577	17,889	5,833	635
Eastern Region % of Population	15.90%	24.29%	19.94%	24.09%
n0=	Initial estimated sample size			25
n=	Final estimated sample size			25.98
p=	Probability of picking response (50% max)			50%
q=	(1=p)			50%
SEM=	Max allowed standard error			10%
N=	Targeted population size			635

Since the total population of large industries in the eastern province is small, all members of the population were invited to participate in the study. Therefore, the survey questionnaire was sent to 153 large industrial sectors in the eastern province of Saudi Arabia. The minimum required sample size is twenty-six.

3. DATA ANALYSIS

The data collected through the questionnaire need to be analyzed statistically to meet the study objectives as shown below.

1. **Owner Selection System:** A simple mathematical calculation was used to show the percentage of selection systems that are used in the industrial sector in the eastern province of Saudi Arabia.
2. **Owner A/E Selection Criteria:** A simple mathematical calculation was used to count the number of selection criteria used in the owners' selection systems in the industrial sector in the eastern province of Saudi Arabia.
3. **Evaluate the Degree of Importance of Each Selection Criteria to Select an A/E:**
Simple statistical calculations were used to calculate the average mean, standard deviation, and relative importance index for each selection criteria in selecting an A/E.
4. **Evaluate the Degree of Influence of Selection Criteria on Each Project**
Constraint: Simple statistical calculations were used to calculate the average mean, standard deviation, and relative importance index for the influence of each selection criteria on each project constraint.

4. DEVELOP QFD MODEL

4.1 OVERVIEW

Quality function deployment (QFD) was originally developed in Japan in the late 1960s and early 1970s, was applied in the US in the 1980s, and then later in other industries. QFD is defined as “an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (i.e., marketing strategies, planning, product design

and engineering, prototype evaluation, production process development, production, sales)’’ (Sullivan, 1986). Akao (1990) described QFD as, “a method for developing a design quality aimed at satisfying the customer and then translating the customer’s demand into design targets and major quality assurance points to be used throughout the production phase”. Shortly after, Eureka and Ryan described QFD as a “customer-driven planning process” (Day, 1993). Hauser and Clausing, on the other hand, described QFD from a more organizational view, in which they focused on organizational communication and teamwork: “Quality function deployment focuses and coordinates skills within an organization, first to design, then to manufacture and market goods that customers want to purchase and will continue to purchase” (Hauser & Clausing, 1988).

There has been ample research on QFD. Overall, these papers can be categorized into four main categories: general introduction, functional field, application industry, and theoretical development (Chan et al., 2002). Many drivers have contributed to the evolution of QFD between 1967 and 1972, but the two main drivers that led to its stability and diffusion in Japan were to improve the design of quality and to provide manufacturing and field staff with a planned quality control chart (Lock & Dennis, 1994). Later, QFD was successfully used in many Japanese industries, such as consumer electronics, construction equipment, agriculture systems, home appliances, software systems, integrated circuits, steel, synthetic rubber, and textiles (e.g., Akao, 1990; Hauser & Clausing, 1988; Kim & Moskowitz, 1997).

QFD was well-known in Japan; however, after publishing research papers in prestigious journals (e.g. “Quality function deployment and CQWC in Japan” (Prasad, 1998)), QFD started to be recognized widely in the US. Specifically, the annual QFD Symposium held in Michigan in 1989 and its documents have become important

publications on QFD (Chan et al., 2002). Later on, the impact of QFD exceeded Japan and the United States into Australia, Belgium, Brazil, Denmark, Fenland, Germany, Hong Kong, India, and Ireland, to name a few. Now, the annual International Symposium on QFD is held in the US and other countries.

Preece et al. (1998) asserted that "rewards go to those who can best understand customer needs and deliver the greatest value to their clients". In other words, companies that meet their customers' quality expectations will receive better benefits on the long term. In general, QFD is based on a thorough analysis of customers' feedback.

Specifically, the main functions of QFD are product development, quality management, and customer needs analysis (Chan et al., 2002). Other functions may include design, engineering, management, planning, decision-making, timing, teamwork, and costing.

Many research papers have indicated that QFD has decreased design costs by 60% and design time by 40% (Benner et al., 2003). Further, QFD has been and is being applied in a wide range of industries. Shipbuilding and electronics were the first two early applications. Other applications focus on automobiles, electronics, and software systems.

Nowadays, QFD has also been introduced to the service sector, such as banking and accounting, health care, education, and research. Indeed, the applications of QFD are wider than ever before, and beyond the abovementioned general industries, QFD has inspired many other industries such as agriculture, aerospace, construction, environment protection, and disaster prevention. Dikmen et al. (2005) listed a number of benefits that have been observed for QFD, such as exact collection and identification of client requirements, better planning, better communication and concurrency, reduced uncertainty, etc. (Akao, 1994).

Overall, there are two common QFD models. The first model is the Four-Phase model, also known as the Clausing model or the ASI Model. The second one is Akao's Matrix of Matrices Model (Chan & Wu, 2002). The Four-Phase Model is a product development design that covers basic product development steps, while the matrix model is designed for Total Quality Management (TQM) and includes a range of activities, such as reliability planning, value engineering, cost analysis, and manufacturing quality control that are implicit or optional in the Four-Phase model (Gunther, 2000).

The Matrix-of-Matrices model, also called the Akao QFD model, is based on a system of thirty matrices, charts, tables, or other diagrams. This model focuses on strong continuous improvements through several phases of product development, with the development team being expected to create its own QFD model, because no two projects are identical.

Jafari (2013) discussed previous studies on the top criteria for selecting contractors and listed valuable criteria from different resources. Mostly, the criteria are valuable and applicable for the selection of A/Es as well. The study also discussed different evaluation methods for contractor selection that could be implement when evaluating consultants as well. The research focused on the Quality-Function-Deployment (QFD) method as an evaluation tool. QFD is the optimum tool for evaluation and selection because it links the selection criteria to the project constraints.

The QFD model is explained graphically by the House of Quality, as shown in Figure 4.

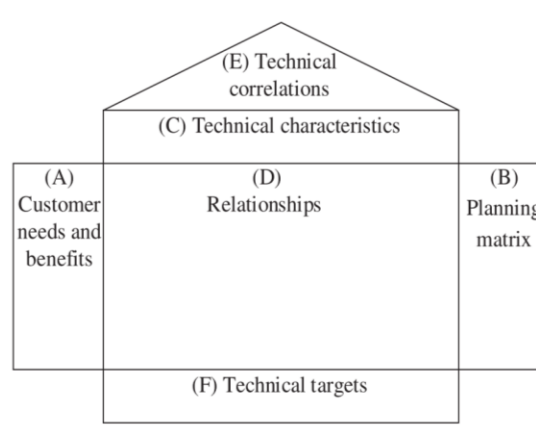


Figure 4. House of Quality

The standard method for the House of Quality investigates the technical correlations (E) in how to achieve the customer's needs and benefits (A). This is mostly applicable in industrial production processing, but the QFD model that will be discussed later is for servicing providers (A/E). In the A/E application, there is a slight deviation from the QFD standard model by excluding the technical correlations, as discussed by Jaffari (2013). The same concept will be applied for the A/E selection model in the upcoming section.

4.2 DEVELOP A QUALITY FUNCTION DEPLOYMENT MODEL FOR A/E SELECTION

The QFD model concept is a tool that will be used to assist owners in selecting an A/E. The project constraints will be defined, which include quality, time, and cost. Then, the A/E selection criteria need to be identified and linked to the project. The model will be

oriented to the customer's voice to select the most suitable A/E. Jafari (2013) applied QFD as a pre-qualification model to pre-qualify contractors for selection. The same concept will be used but will be applied as an evaluation model for the selection of a consulting and designing office.

The QFD model consists of the following steps:

1. Step 1 - Identify the Data Matrix Elements:

- a. List of Project Constraints (WHATs): This includes the project constraints that the customer requires to complete the project successfully, including quality, time, and cost.
- b. List of Selection Criteria (HOWs): This includes the required A/E abilities to achieve the project constraints.
- c. The Importance Weight of Selection Criteria (IH_i): This is the results from the survey measuring the importance of A/E characteristics and abilities selection criteria. The scale of the importance weight is between zero to one hundred, and the sum of weight is equal to one hundred.
- d. The Influence of Selection Criteria on the Quality Constraint (S_{1n}): This includes the results from the survey measuring the influence of the selection criteria on the quality constraint. The scale of interrelation is between zero to one, where zero means there is no interrelation, and one has the highest interrelation.
- e. Measuring the Influence of Selection Criteria on the Time Constraint (S_{2n}): This includes the results from the survey measuring the influence of the selection criteria on the time constraint. The scale of interrelation is between zero to one, where zero means there is no interrelation, and one has the highest interrelation.

- f. Measuring the Influence of Selection Criteria on the Cost Constraint (S3n): This includes the results from the survey measuring the influence of the selection criteria on the time constraint. The scale of interrelation is between zero to one, where zero means there is no interrelation, and one has the highest interrelation.

Figure 5 describes the elements of the QFD data matrix.

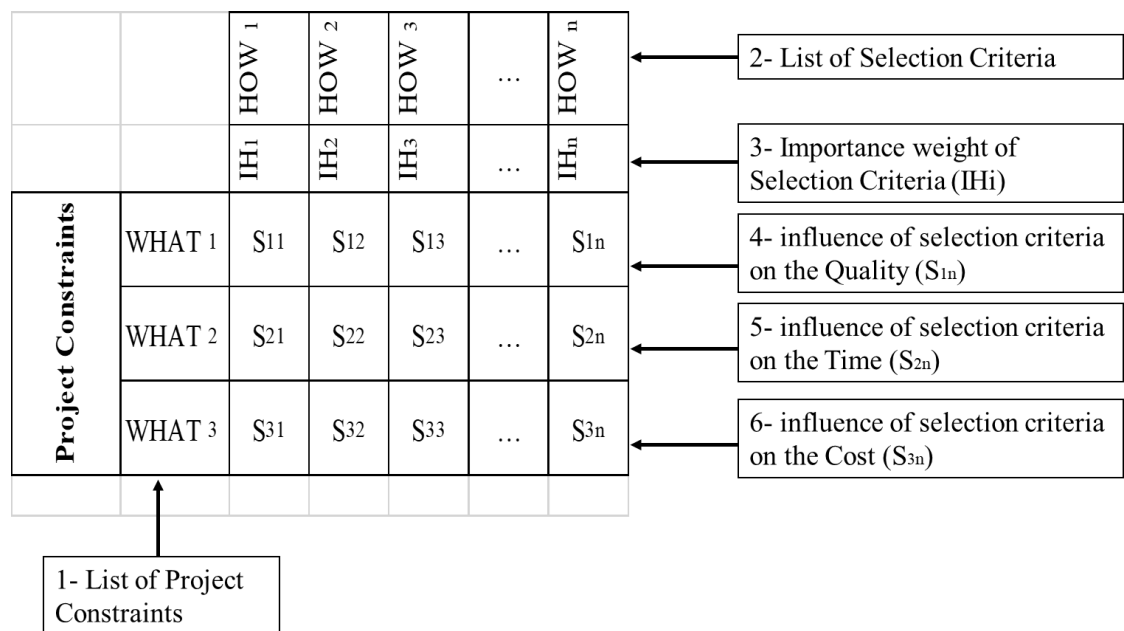


Figure 5. Elements of QFD Data Matrix

2. Step 2 - Evaluation of A/E in the QFD Process Matrix: In this step, there will be two variables that need to be measured.

- a. The Importance of Each Project Constraint (WHATs) to the Owner (PWi): The owner will need to identify the importance degree of the project constraints quality, time, and cost. The scale of importance for each project constraint will be 0 (without importance), 0.2 (lowest importance), 0.4 (low importance), 0.6 (medium importance), 0.8 high importance, and 1 (highest importance).
- b. The A/E Performance Evaluation (PHi): The A/E will be evaluated based on his performance in each selection criteria for his past or present projects. The client needs to have this information from historical data, reference customers, or a third party. The performance of the A/E in each selection criteria (HOW) will be evaluated on a scale between zero to one in the QFD process matrix. Figure 6 describes the process matrix.

			Selection Criteria				
			Quality Performance	Technical Experience	Past Performance	...	Project Engagement
			PH ₁	PH ₂	PH ₃	...	PH _n
Project Constraints	Quality	PW ₁	R ₁₁	R ₁₂	R ₁₃	...	R _{1n}
	Time	PW ₂	R ₂₁	R ₂₂	R ₂₃	...	R _{2n}
	Cost	PW ₃	R ₃₁	R ₃₂	R ₃₃	...	R _{3n}

7- Importance of project constraints to the owner (PWi)

8- The consultant performance evaluation (PHi)

Figure 6. The Process Matrix of the QFD Process Model

3. Step 3 - Calculating the Point Scores (R_{ij}):

The process matrix of the QFD process model as shown in Figure 7 has dependent variables that need to be calculated. In this step, the point score (R_{ij}) of the intersection between each *WHAT* and *HOW* will be calculated as shown in equation 1:

$$R_{ij} = PW_i \times (IH_i \times PH_i) \times S_{ij} \quad (1)$$

Where:

R_{ij} is the point score for the intersection between *WHAT* and *HOW*

PW_i is the importance of project constraints (*WHAT*) to the owner (step 2)

IH_i is the importance weight of selection criteria (step 1)

PH_i is the A/E performance evaluation (step 2)

S_{ij} is the strength of the interrelationships between $WHAT_i$ and HOW_j (step 1)

4. Step 4 - Calculating the Pre-qualification score (PS): The pre-qualification score for *WHAT* (PSW_i) is calculated as shown in equation 2:

$$PSW_i = \sum_{j=1}^n R_{ij} \text{ for } 1 \leq i \leq m \quad (2)$$

The pre-qualification score for *HOW*_j (PSH_j) is calculated as shown in equation 3:

$$PSH_j = \sum_{i=1}^n R_{ij} \text{ for } 1 \leq j \leq n \quad (3)$$

The pre-qualification score (PS) for a specific A/E is calculated using Equation 4 is shown below:

$$PS = \sum_{i=1}^m PSWi = \sum_{i=1}^n PSHj \quad (4)$$

The calculation of point scores for equations 1, 2, 3, and 4 are shown the QFD evaluation process matrix in Figure 7.

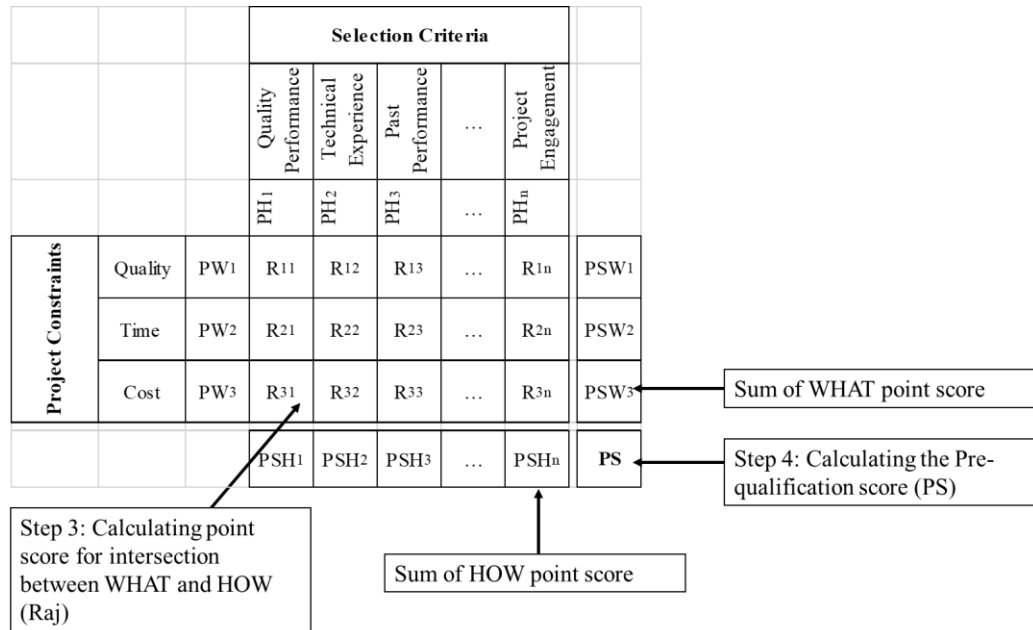


Figure 7. QFD Evaluation Process Matrix

5. Step 5 - Calculating the Consultant Pre-qualification Index (*CPI*) and Ranking:

The A/E Consultant Pre-qualification Index (*CPI*) for the specific A/E is calculated as shown in equation 5:

$$CPI = \frac{PS}{MaxPS} \quad (5)$$

Where:

PS is the pre-qualification score calculated in equation (4)

MaxPS is the maximum score of pre-qualification that an A/E can achieve, where the entire statues of the *HOWs* are rated at their highest value. In order to calculate the value of *MaxPS*, the PHj needs to be replaced with one, which is the highest score in equations 1, 2, 3, and 4. After that, the A/E will be ranked based on the calculated value of *CPI*.

The results are to be summarized in a table that includes the A/E name or number, CPI score, and rank (such as in the sample Table 3).

TABLE 3. Sample A/E Score Summary Table

A/E	CPI Score*	Rank
1	0.60	1
2	0.50	2
3	0.39	3
4	0.20	4

*A/E Pre-qualification Index (equation 5)

A summary of the QFD process model steps is summarized as shown in Figure 8.

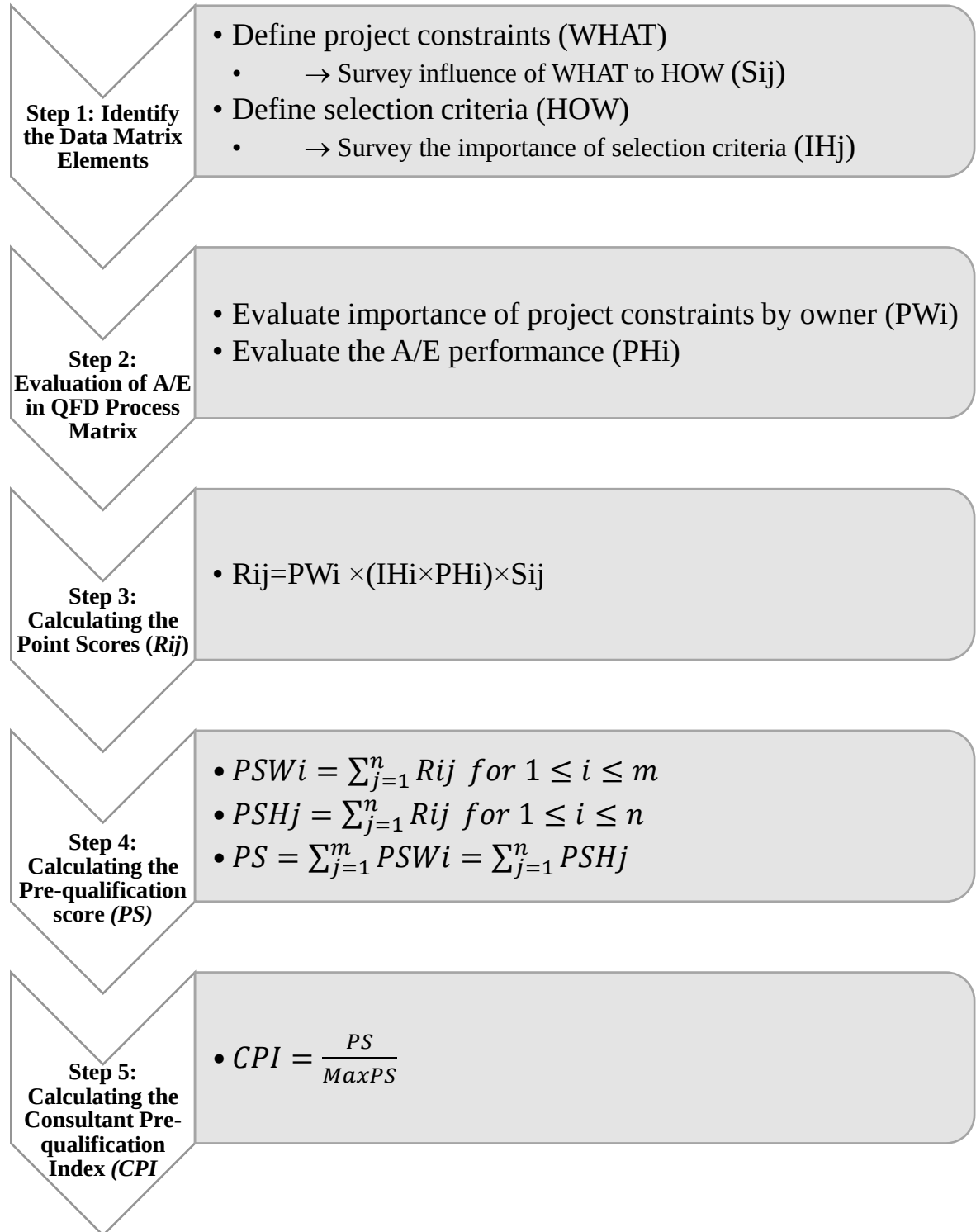


Figure 8. Summary of the QFD Process Model

4.3 MODEL VALIDATION

At least three owner organizations will be selected to apply the developed model in selecting A/Es for their perspective projects. Each organization will be requested to select the A/E using their system, and then the developed model will be used to select the same. A detailed qualitative analysis will be performed to show the differences between the outcomes of both systems.

The proposed model for this research is presented in Figure 9. The research model shows the plan for how the research is to be implemented from the literature review to the survey for the required data, to developing the QFD model, and testing the model for comparison and synthesis.

In summary, this study aims to systematically identify and analyze current methods for procurement of A/E services, which will aid in understanding different procurement approaches and their underlying assumptions. To achieve this goal, the owner's existing methods of procuring A/E services need to be investigated. After that, the current practices of project owners in evaluating A/Es need to be surveyed to identify the most prominent methods in the market. There will be studies to evaluate the importance of A/E selection criteria and to evaluate the influence of the selection criteria on the project constraints. The results of the research will lead to the development of a model that can assist owners in selecting the most suitable A/E for their needs. The QFD Model will be the developed model that needs to be tested and compared with the owner's A/E selection system.

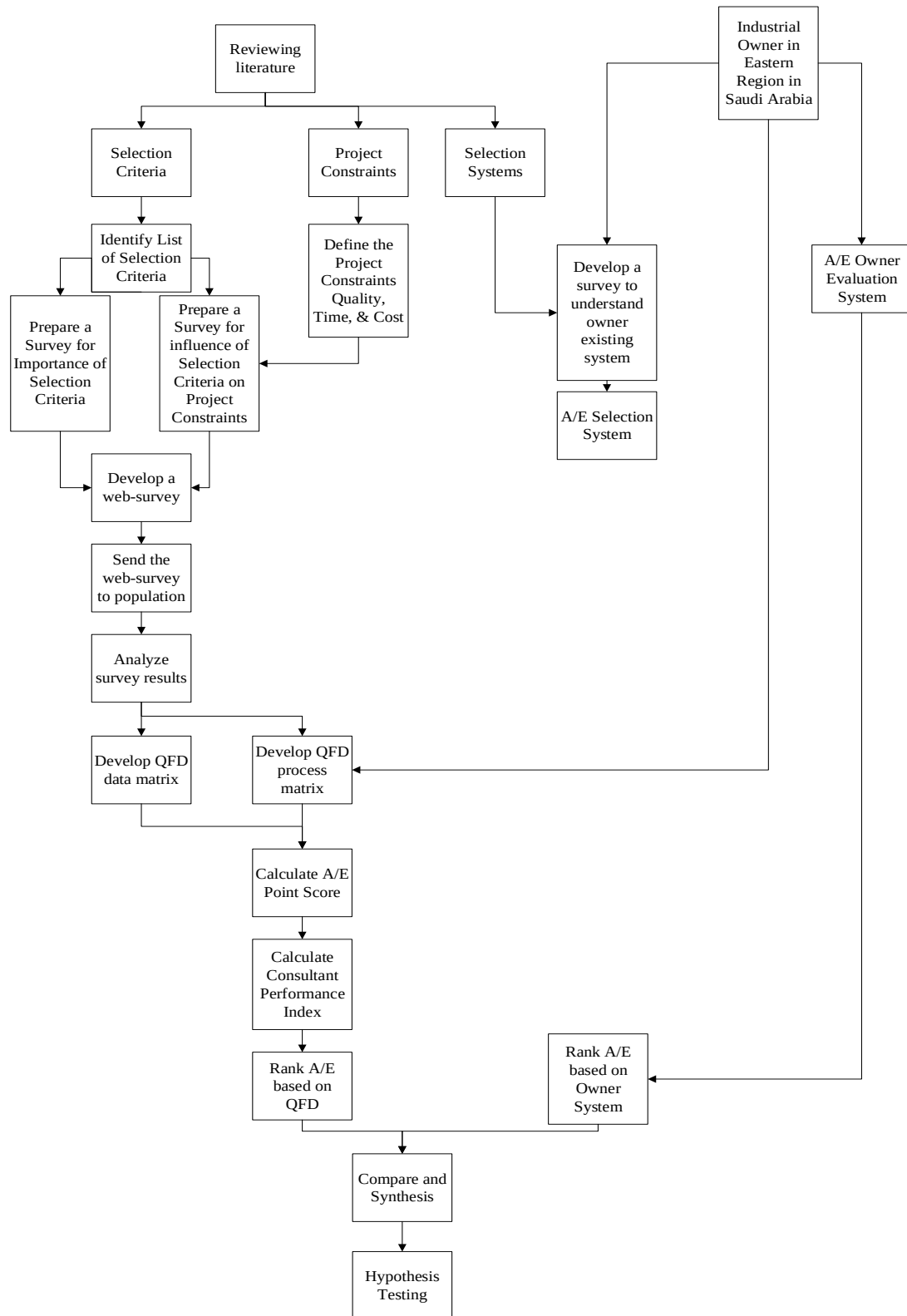


Figure 9. Proposed Research Model

CHAPTER 4: RESULTS AND DISCUSSION

The developed structured questionnaire was emailed in the last quarter of 2019 to 153 large industrial owners in the eastern province of Saudi Arabia. Recipients were asked to participate in the study and respond to the questionnaire online within two to three weeks. The questionnaire was followed up by emails, telephone calls, and personal visits to encourage those owners to participate in the study. Unfortunately, despite those efforts, only twenty-eight owners properly completed and returned the questionnaire. The rate of return was 18.3%, which is considered moderately below the typical norm of a twenty to thirty percentage response rate in most postal questionnaires surveying the construction industry (Akintoye & Fitzgerald, 2000). However, twenty-eight is a greater number than the calculated minimum sample size and, therefore, the respondents form a reliable, acceptable, and representative sample.

The characteristics of the participants, the owners of the current A/E selection systems, the A/E selection criteria, the project constraints, the importance of A/E selection criteria, the influence of A/E selection criteria on the project constraints, and the QFD model development are presented in the following sections.

1. CHARACTERISTICS OF THE RESPONDENTS

The respondents' characteristics are described by the respondents' job titles, level of education, years of experience in construction projects, years with the current employer, and the respondent's role in the A/E selection process.

1.1 RESPONDENT JOB TITLE

The results indicated that the majority (75%) of the respondents are from the top management positions of Director/VP, Manager, Managing Director, and Senior Manager. The remaining 25% of respondents are engineers. Figure 10 illustrates the job title distribution of the respondents.

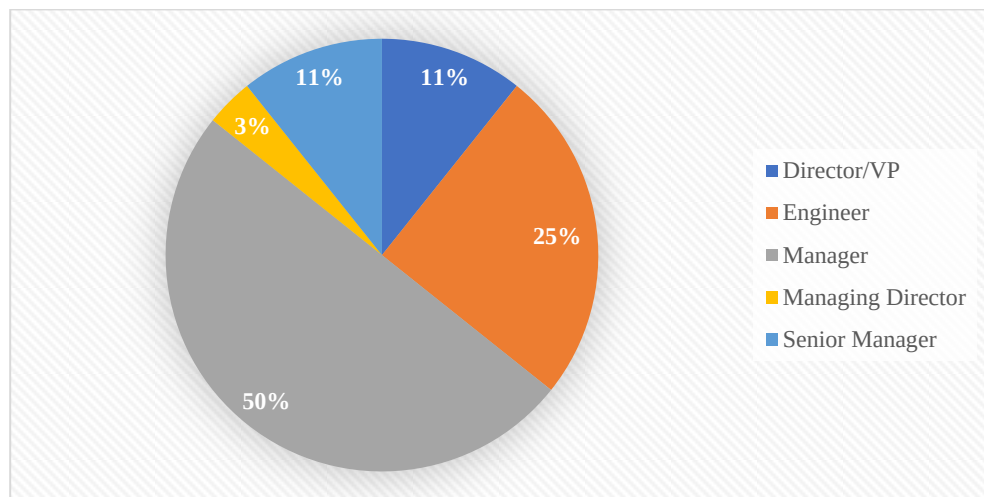


Figure 10. Respondent Job Titles

1.2 RESPONDENT LEVEL OF EDUCATION

The results indicated that the majority (96%) of the respondents are highly educated, with bachelor's and master's degrees. About 21% of those respondents hold master's degrees above their bachelor's degree. Figure 11 presents the respondents' level of education distribution.

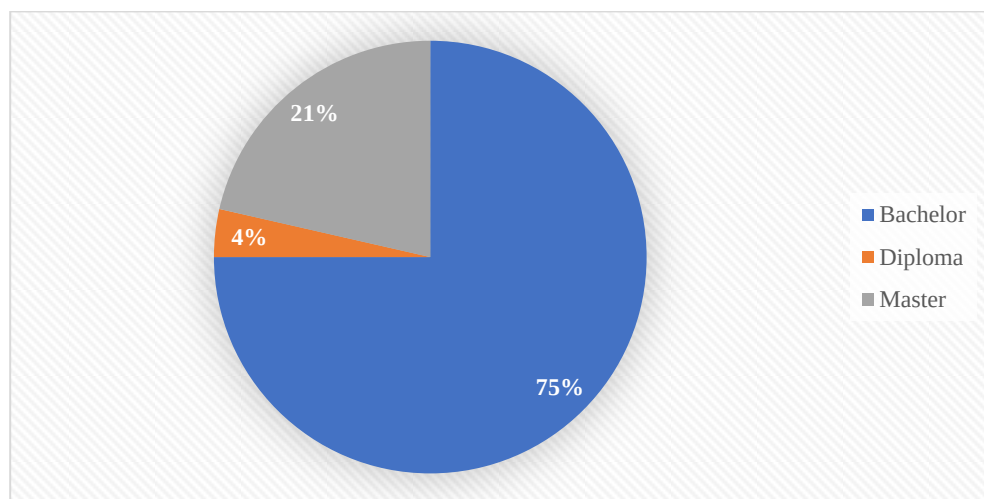


Figure 11. Respondent Level of Education

1.3 RESPONDENT YEARS OF EXPERIENCE

The majority (68%) of the respondents have more than ten years of experience in construction projects. The remaining (32%) respondents have ten years of experience but equal to or greater than five years of experience. The distribution of the respondent's years of experience in construction projects is illustrated below in Figure 12.

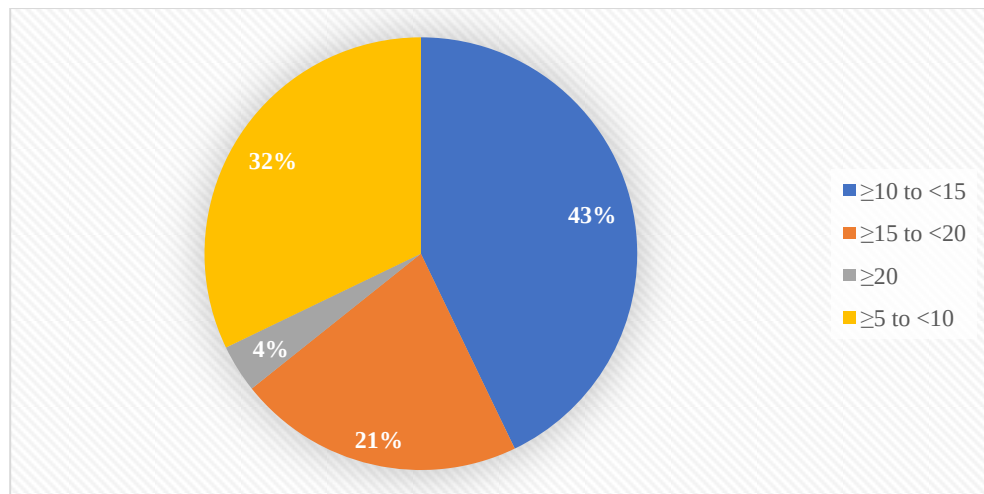


Figure 12. Respondent Years of Experience

1.4 RESPONDENT YEARS WITH CURRENT EMPLOYER

The results indicate that the majority (89%) of the respondents have earned their years of experience from their current employers. Only 11% of the respondents have been with their current employers for less than five years. The respondents' years with the current employer are shown in Figure 13.

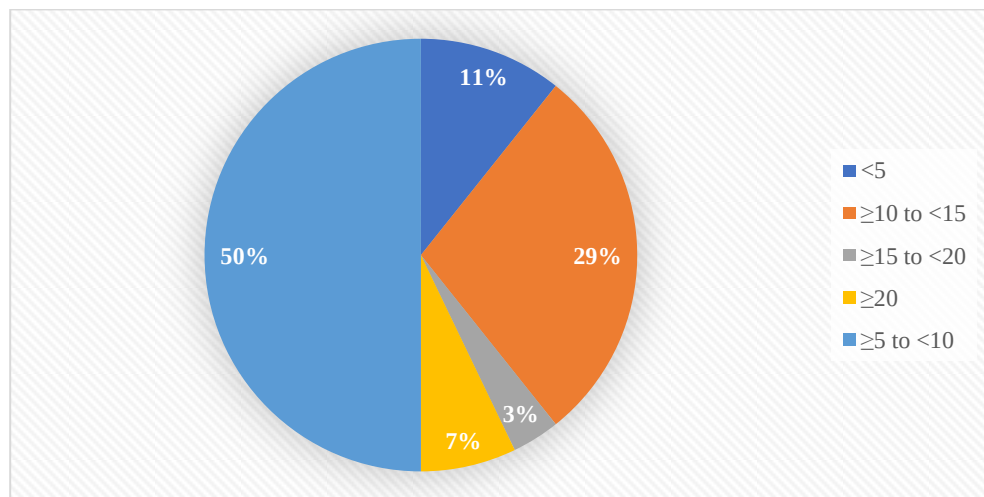


Figure 13. Respondent Years with Employer

1.5 RESPONDENT ROLE IN THE A/E SELECTION PROCESS

The results indicate that all the respondents participate in the A/E selection process. Seven percent of the respondents have chaired committees for selecting A/Es, and the majority (82%) of respondents have served on committees charged with selecting A/Es. The respondents' roles during the A/E selection process are shown in Figure 14.

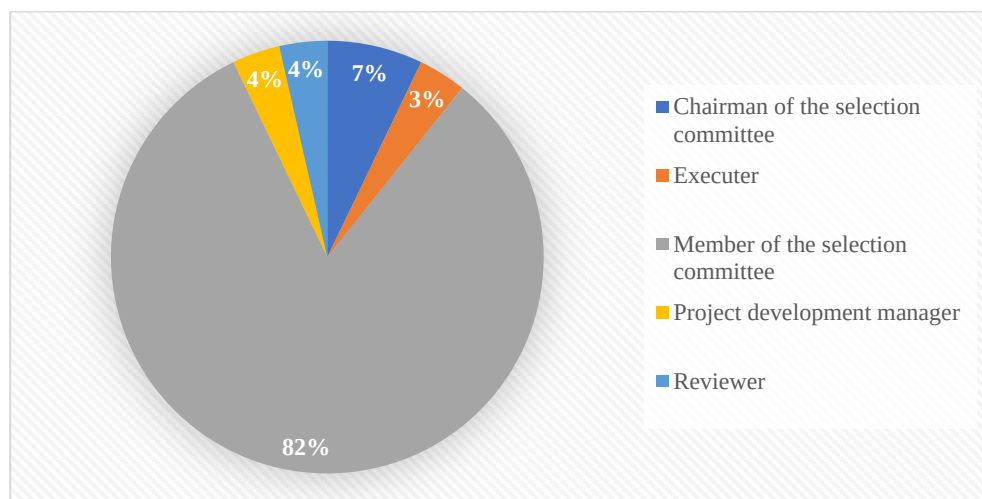


Figure 14. Respondents' Role in A/E Selection Process

It is evident that the respondents are well informed in the A/E selection systems. Therefore, obtaining the required data from such caliber sources increases the reliability and validity of the results of the study.

2. CHARACTERISTICS OF THE RESPONDENTS' ORGANIZATIONS

The characteristics of the respondents' organizations are described by the organization types, line of business, number of employees, average A/E designing cost, and the average annual projects cost.

2.1 TYPE OF ORGANIZATION

The results indicate that the majority (93%) of the organizations are private and semi-private sectors, while the remaining 7% are governmental organizations. The results indicate that most respondents have more flexibility in A/E selection based on quality rather than price. Figure 15 illustrates the respondents' types of organizations.

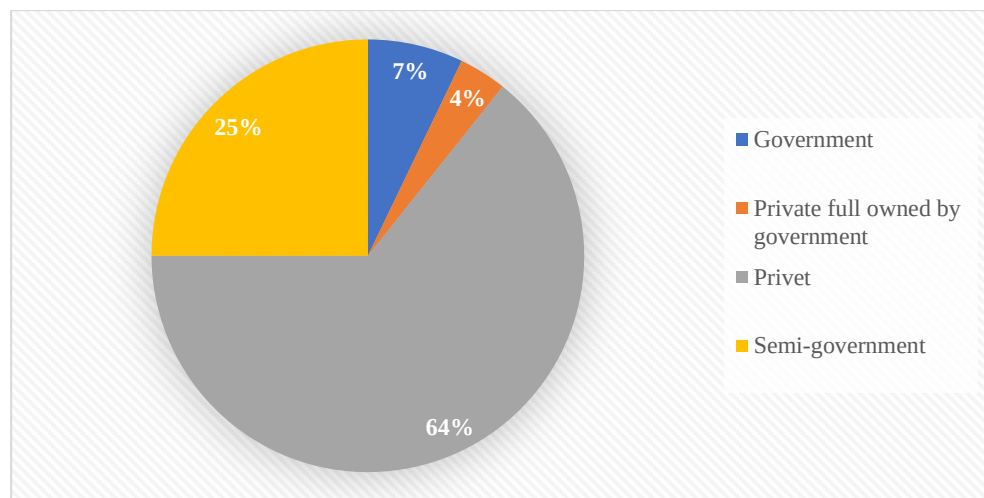


Figure 15. Owner's Type of Organization

2.2 ORGANIZATION LINE OF BUSINESS

The results indicated that the majority (85%) of the respondents are industrial companies with different business lines. About 15% of the respondents are management services providers and others. The results indicate that the targeted industrial organizations were reached for data collection. Figure 16 describes the different organization lines of business.

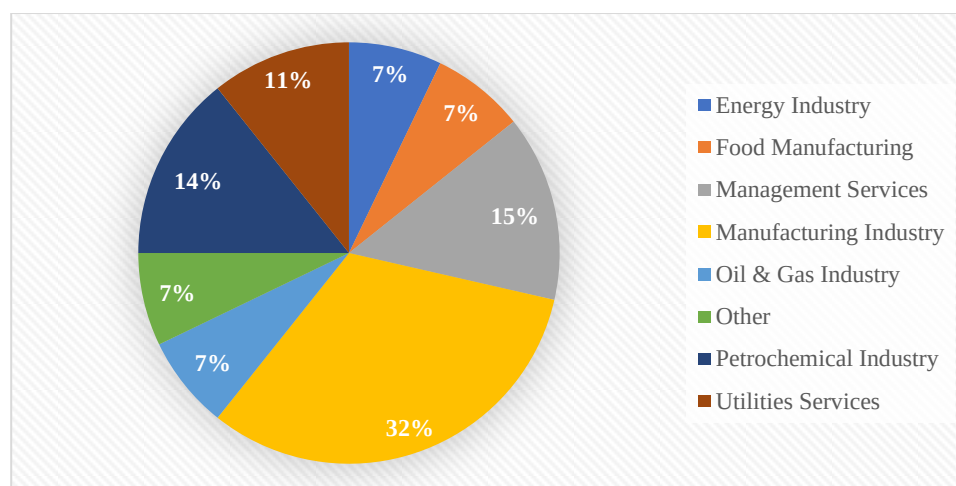


Figure 16. Owner Line of Business

2.3 ORGANIZATION SIZE

The results indicate that the majority (86%) of the respondents' organizations have more than 250 employees. Only 14% of the organizations have fewer than 250 employees. The research study focuses on large-size industrial establishments, which was achieved as per the results. An illustration of the organization sizes is shown in Figure 17.

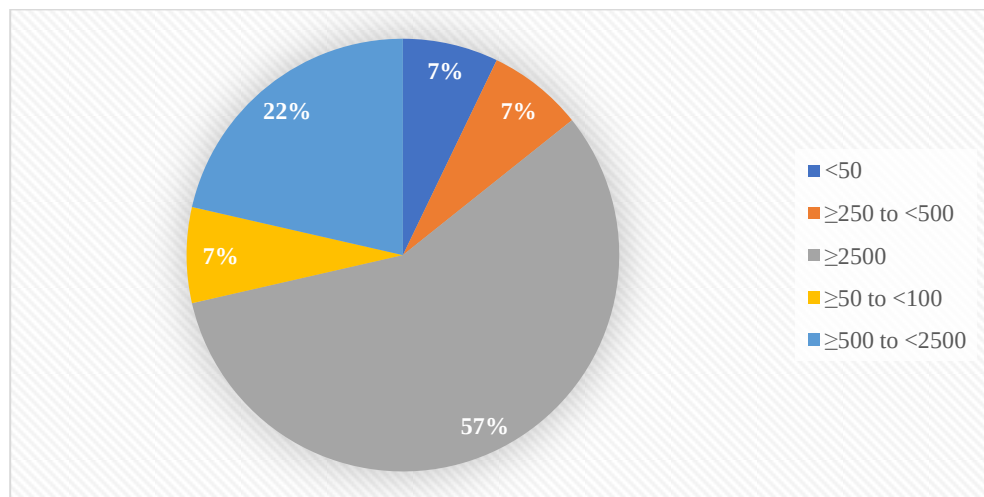


Figure 17. Owner Size (Number of Employees)

2.4 RESPONDENT ORGANIZATION AVERAGE A/E CONTRACT DESIGN VALUE

The results indicate that all the respondents had A/E designing services with different contract values. The majority (82%) of the respondents procured designing services for SR1 million or more. The remaining 18% had a contract design value between SR50,000 and SR1 million. The results provide an indication that, with such values for designing services, A/Es need to be selected properly with care to provide the required level of services. An illustration of the average A/E contract design value is shown in Figure 18.

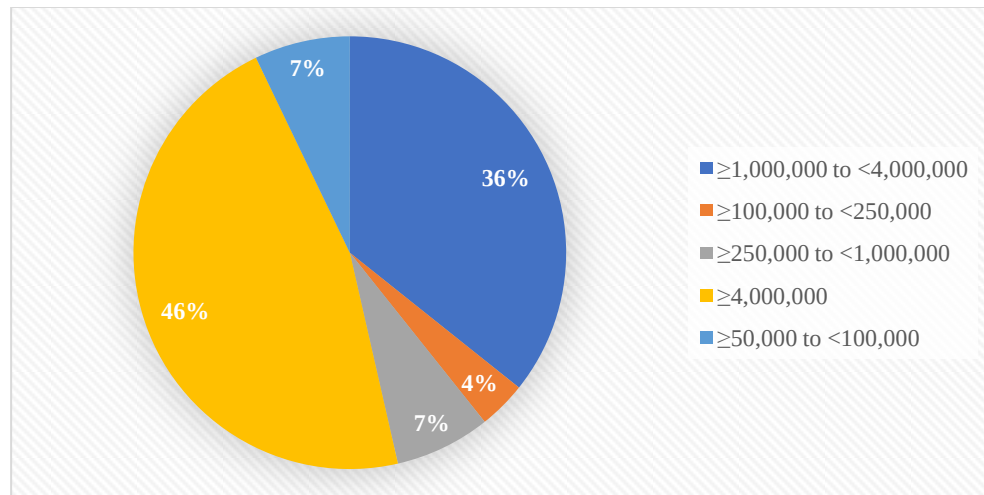


Figure 18. Average A/E Contract Design Value (SR)

2.5 ORGANIZATION ANNUAL AVERAGE PROJECT SIZE

The results indicate that all the respondents' organizations have annual multimillion projects. The majority (89%) of the respondents have an annual average project size of SR30 million or more. The remaining 11% have an annual project size of SR10 million or less. Figure 19 illustrates the organizations' annual average project size. With such multimillion investments, A/E is a key factor toward maximizing the benefits of the project investments. If we compare the ratio between the average design costs with the average project cost, the number indicates that the design cost is minor compared to the project cost. The second highest average project cost is between SR70 million and SR100 million, and the second highest design cost is between SR1 million and SR4 million. This shows a ratio between 1/7 and 4/100, which indicates that the design cost is between 1.4% and 4% of the project total cost. This provides an indication that the A/E needs to be selected based on the benefits to the project's total cost rather than from saving on design value.

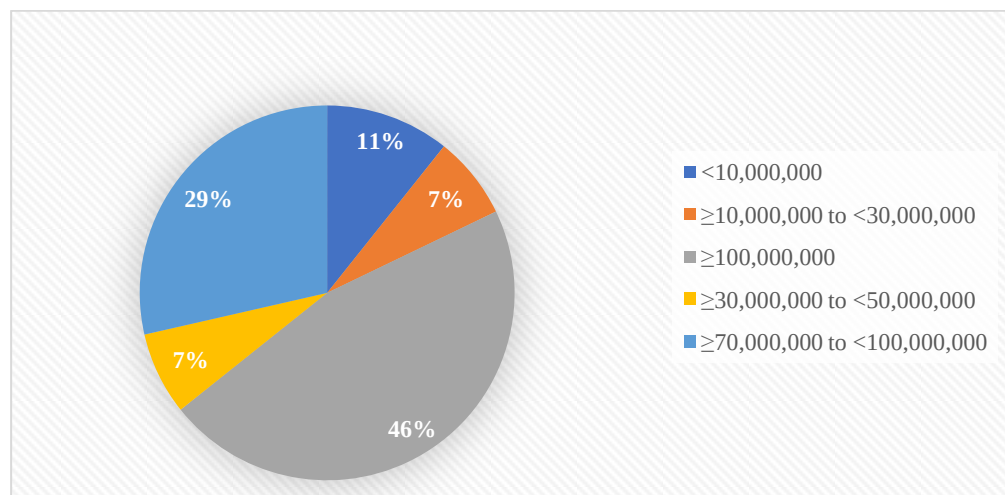


Figure 19. Annual Average Project Value (SR)

3. OWNER CURRENT A/E SELECTION SYSTEM

The results indicate that the majority (64%) of the respondents declared that their organizations send invitations to submit qualification statements and quotations to A/Es who are in their employers' lists. The remaining organizations do not have a list of potential A/Es to select from for upcoming design projects. Figure 20 presents the responses of the participants regarding preparation of a list of potential A/Es.

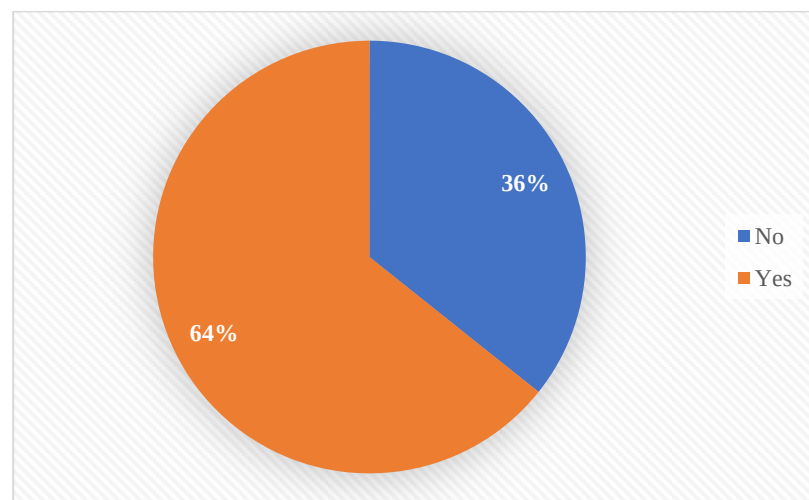


Figure 20. Existence of a List of Qualified A/Es

The respondents indicated that they prepare a list of potential A/E offices to be invited to compete for a project. The list of potential A/E offices is extracted either from the company's general list or from the industry in the absence of a company's general A/E list. The selection of those A/E offices is based on a single criterion or multiple criteria. The results indicated that the 32% of the respondents use three criteria: The A/E design specialization, the type of project to be designed, and the A/E's past experience in similar projects. Interestingly, the results indicated that 25% of the respondents use the design specialization only for selecting A/E offices for the list. Moreover, about 14% of the respondents use two criteria, including the A/E's design specialization and the type of project to be designed when selecting A/E offices for the list. Also, 14% of the respondents indicated that they use only the type of project to be designed to select A/E offices for the list. The criteria used by the project owners in selecting A/E offices for the list of who will be invited to compete for the design are shown in Figure 21 below.

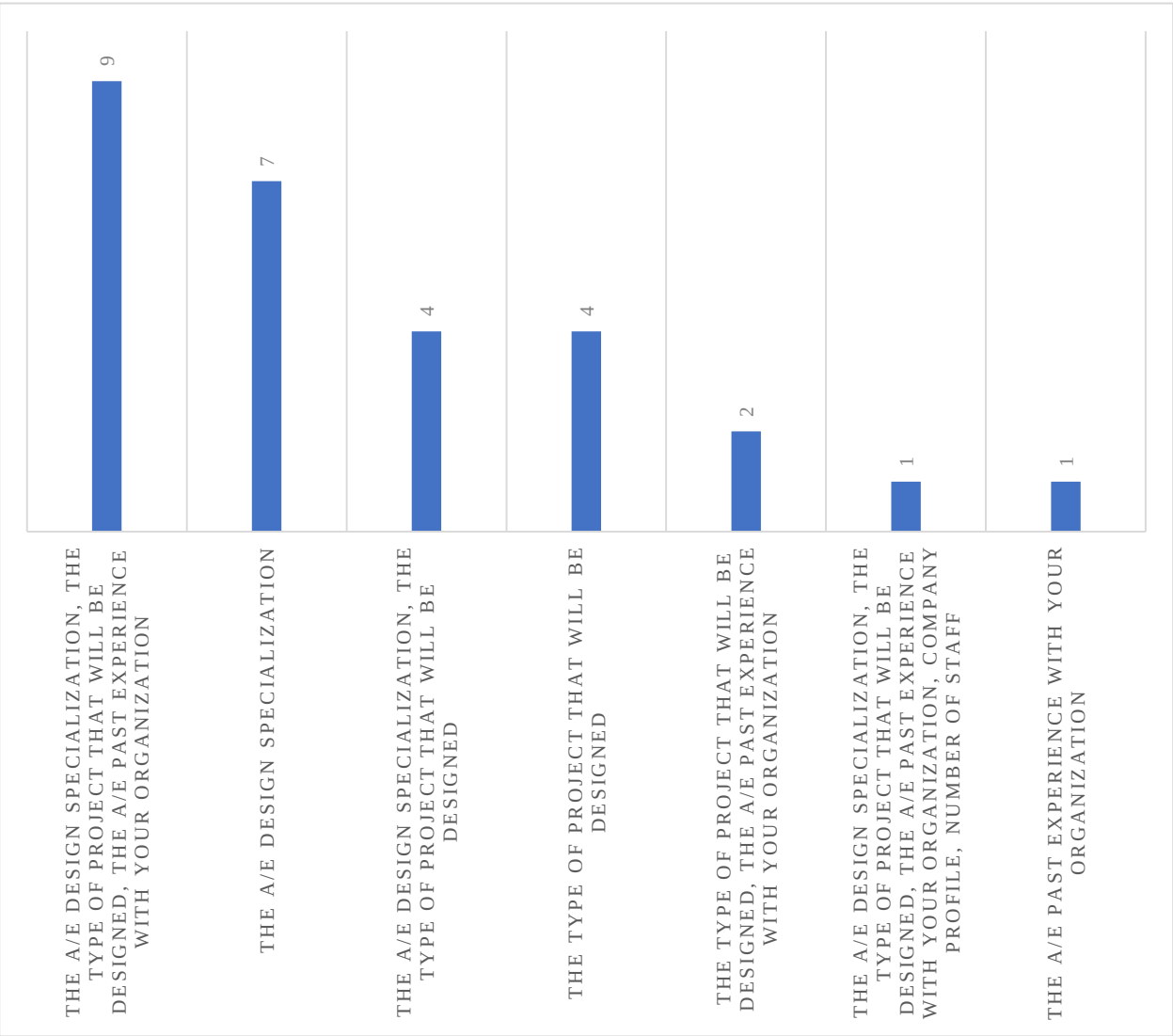


Figure 21. Owners' General Criteria for A/E Selection

Apparently, the owners send a Request for Proposal to the A/E offices on the selected list requesting specific information depending on the A/E selection system used. About 18% and 11% of the owners use the best value and fixed budget/best technical value selection systems, respectively. It seems that those owners use the design-build delivery system. The users of the best value selection system intend to select design-build contractors based on the best price for a given design. The users of the fixed budget/best technical value aim to select design-build contractors based on the best designs for fixed budgets. About 36% and 21% of the respondents select A/Es based on price or quality, respectively. The remaining respondents indicated that their employers use the weighted criteria system for selecting A/Es. Figure 22 presents the distribution of the used A/E selection systems.

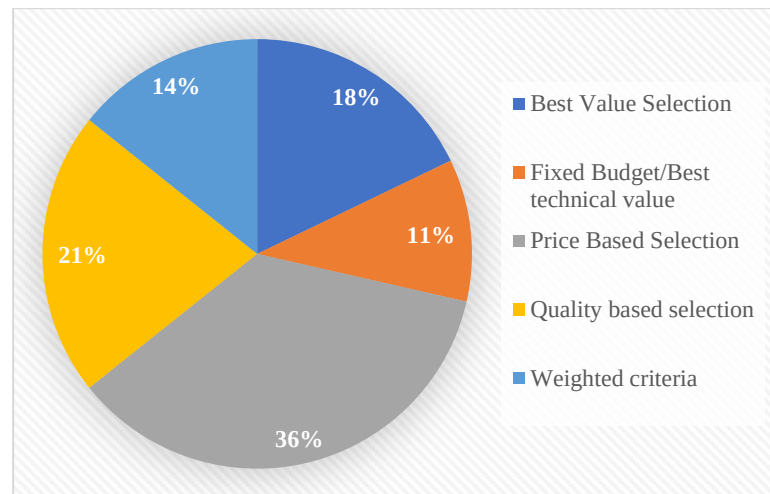


Figure 22. Owners' A/E Selection Systems

3.1 A/E SELECTION CRITERIA

The results indicate that the owners use many criteria to evaluate A/Es in their pursuit to select the most qualified A/E to develop design packages for their industrial projects. All the respondents were found to use customer satisfaction, past A/E performance, and A/E technical experience to qualify A/E offices for developing a design package for their industrial projects. This provides a clear indication of the importance of these three criteria to measure the A/E performance during the selection process. It was observed that the owners want to select an A/E with highest level of technical qualifications and highest successful records in previous projects to achieve customer satisfaction. Moreover, the majority (93%) of the respondents use the key designer criterion in the qualification process. This also shows that the key designer is an important criterion when evaluating A/E performance. The key designer is the leading designer who has a major impact on providing the highest level of design quality and that could provide massive savings on hidden costs during the project construction. About 61% of the respondents indicated that they consider staff quality to qualify A/E offices in the selection process as well. It seems that some owners value the importance of the quality of the staff that will be assigned to the project. The higher the quality of the staff, the higher the possibility of obtaining quality design. Interestingly enough, the design fee criterion was used only by 46% of the owners. It seems that owners value the quality of A/E over the design fee, as they realize savings in project cost is linked to quality design rather than low design fee. About 32% of the respondents indicated that they consider the financial standing of A/Es in the A/E qualification process. It seems that those owners want assurances that eliminate the risk of delays or terminating designing services due to A/E financial issues. The Firm Capacity

criteria was used by only 25% of the respondents. Those respondents had issues with the A/E offices that were not capable of handling their project size. They need to assure that the A/E has the required resources and capabilities to successfully handle their project size.

Number of years in business was used by 18% of the respondents. It seems that those respondents relate technical experience with the number of years of experience. The more years they have in business and projects means a higher level of technical experience. Reputation of the A/E in the market was used by 18% of the respondents. Either those respondents had ethical issues with an A/E, or they want to get recommendations from the market about an A/E to be hired for their project. Percentage of outsourcing work was used by 14% of the respondents, which means they want to assure that A/Es are designing in-house so that they have higher control to provide the required design quality. Only 7% of the respondents use construction estimation quality during A/E in their evaluation systems. It seems they understand the importance and the impact of estimation quality for proper project budgeting and its impact on the project cost. Quality of estimation is a very important criteria to completing projects within budget. The A/E's current workload was used by only 7% of the respondents. Those respondents may have had previous issues with an overwhelmed A/E who couldn't provide their require design package within the required designing service time or as per the required quality. Hiring an overwhelmed A/E will increase the risk of design errors and will result in a lower level of project engagement. Design quality is the most important selection criteria but was used by only 7% of the respondents. Design quality is the deliverable of an A/E designing firm, but it seems that those respondents understand that there might be A/E offices who have high technical qualifications, key designers, past performance, etc. but that could still provide a

poor quality design. If an A/E was awarded a project, they might subcontract the designing services to a lower quality A/E who may provide a poor quality design. Poor quality design will lead to errors during the project construction, which leads to project delays, with the contractor claiming the additional cost.

Design service time is another one of the most important criteria that was used by only 7% of the respondents. It appears that those respondents understand the importance of measuring the A/E performance in service time where delays in providing the design package will lead to delays for the whole project. It was noticed that no one of the respondents used bid quality to evaluate an A/E office. This indicates that none of the respondents observe the importance of bid quality, which is important in assuring that an A/E has the same understanding of owner requirements to successfully provide the required A/E services as per the project constraints. Another criterion that was not used by any respondents is project engagement. It seems that no respondents understood the effect of A/E project engagement in getting the best service. If the designing office gives high engagement to the owner's project, this will lead to a completed project that meets the owner's expectations.

Figure 23 illustrates the list of selection criteria used by the owners in their current systems.

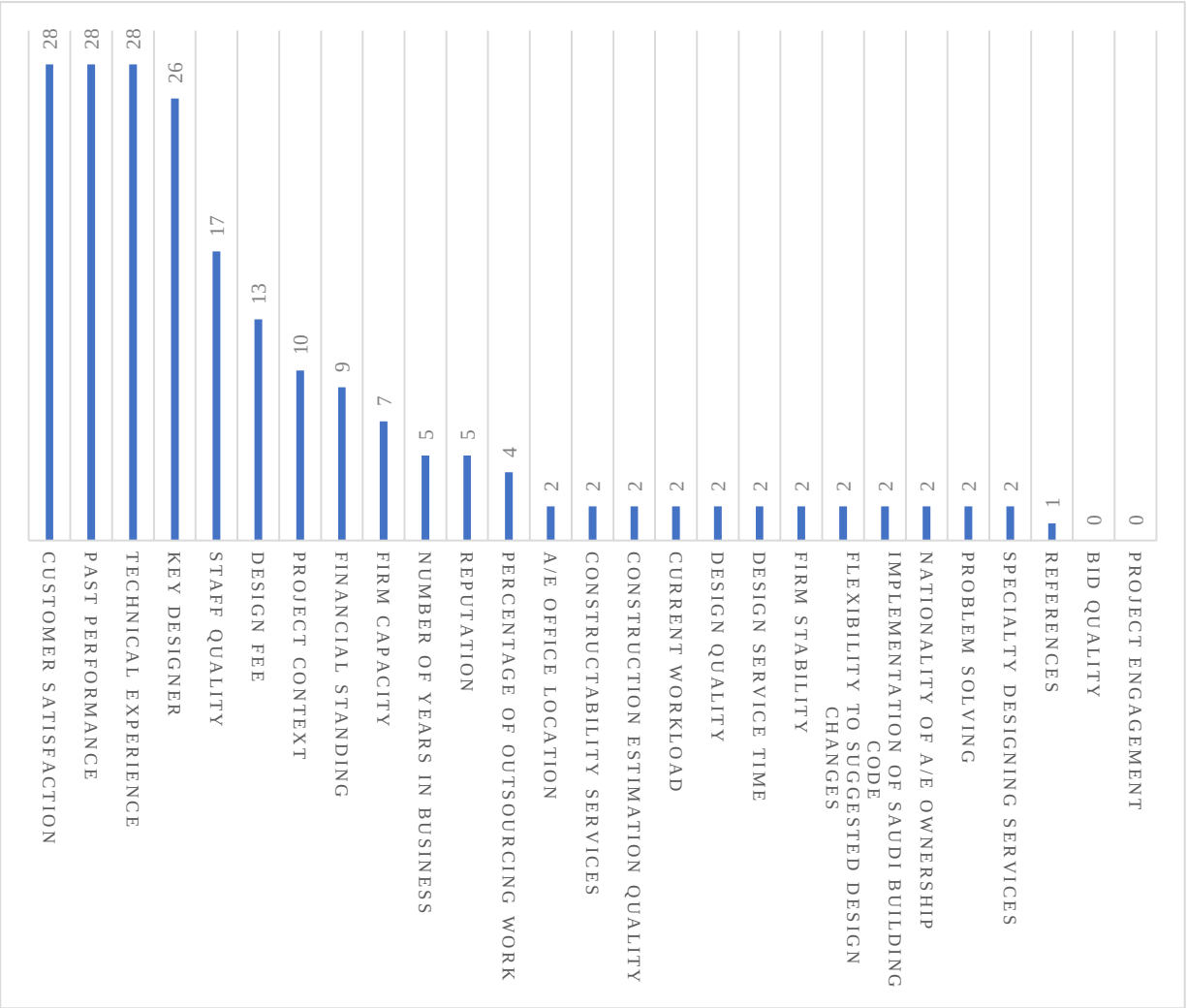


Figure 23. Selection Criteria for A/E Evaluation

3.2 OWNER'S CURRENT SELECTION SYSTEM AND QUALITY

CONSTRAINTS

This subsection evaluates if the current system used by the project owner leads to achieving the project's desired quality. Fourteen percent of the respondents believe that their existing system leads to poor project quality. Low project quality was seen by 18% of the respondents using their current system, with 29% believing that their current system leads to a medium level of desired quality. In the other hand, 21% of the respondents evaluated that the current system leads to high quality, whereas 18% believe that it leads to the desired project quality. This provides an indication that the majority (61%) of respondents need to improve their A/E selection process to achieve a satisfactory level of project quality. The ratings of the current systems to achieve the desired project quality are shown in Figure 24.

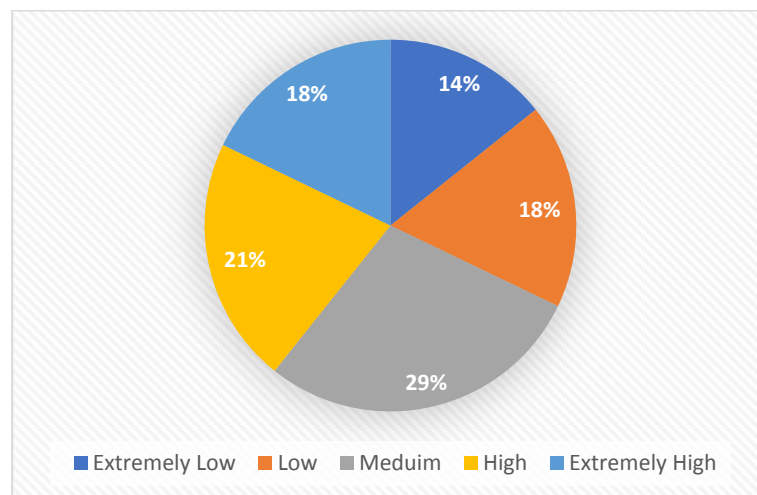


Figure 24. A/E Selection System Effect on Project Quality

3.3 OWNERS' CURRENT SELECTION SYSTEM AND COST CONSTRAINTS

This part investigates if the existing system used by the project owners leads to completing the project within the budget. Three percent of the respondents believe that the current system will not lead to project completion within the budget at all. The majority of the respondents (36%) believe that the existing system is poor in completing projects within budget, while 25% of respondents think that the existing system somewhat will lead to completing the project within budget. On the other hand, 29% of the respondents believe that the existing system is very good at completing projects within budget. Also, 7% of the respondents think that the existing system will lead to completing the project within budget. The majority (64%) of the respondents had issues with A/Es completing their project on budget. It seems that there were design errors during the project construction, which increases the number of contractor claims. Moreover, poor design constructability will cause serious impacts on the project cost. An illustration of the owners' current systems for cost constraints is shown in Figure 25.

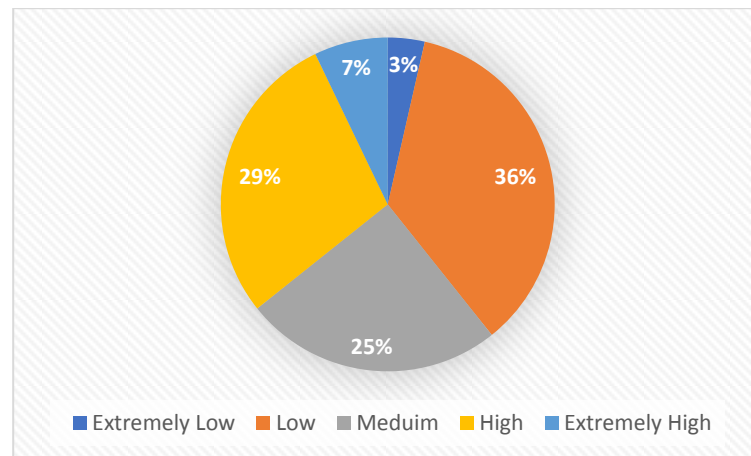


Figure 25. A/E Selection System effect on Project Cost

3.4 OWNERS' CURRENT SELECTION SYSTEM AND TIME CONSTRAINTS

This section explores if the current system used by the owners leads to completing projects on schedule. Seven percent of the respondents think that the current system will not lead to completing projects on schedule at all, while 39% of the respondents believe that the current system is very poor in helping complete a project on time. Eleven percent of the respondents think that the current system somewhat will lead to completing the project on schedule. On the other hand, 18% of the respondents think that their existing system is a very good system toward completing projects on time, and 25% of the respondents believe that the existing system will lead to completing projects on schedule. About 57% of the respondents have issues with A/Es overrunning the project schedule. This might be due to poor design constructability, design quality, technical experience, etc., and the project owners need to improve the selection process to ensure their projects are completed on time. An illustration of the owners' current systems and time constraints are shown in Figure 26.

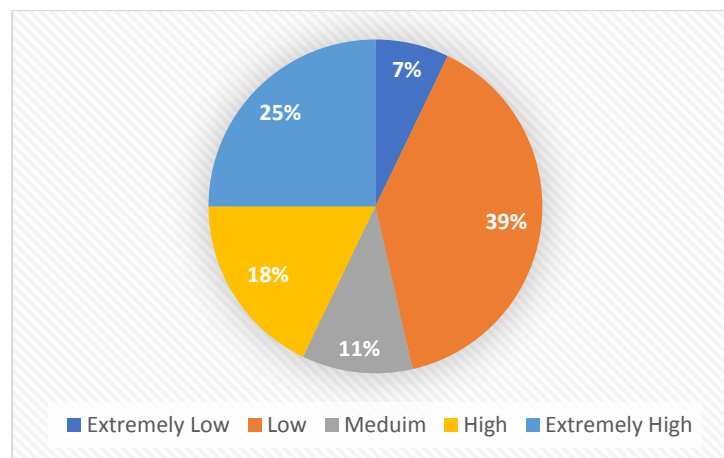


Figure 26. A/E Selection Systems' Effect on Project Time

3.5 EFFECTIVENESS OF THE OWNERS' CURRENT SYSTEM:

This section discusses if the owners' current systems are effective in selecting the most proper A/E for designing the project. Eleven percent of the respondents believe that the current A/E selection system is not effective at all and needs to be replaced by another proper system, while 32% of the respondents believe that the current system is very poor at selecting an A/E for designing services. Twenty-nine percent of the respondents think that the current system is somewhat effective in selecting a proper A/E. In the other hand, 14% of the respondents think that the current system is very effective at selecting the most proper A/E. Fourteen percent of the respondents believe that the current system is an effective system for selecting the proper A/E for the prospect. These results indicate that the majority (72%) of the respondents need to improve their A/E selection system to become effective. This research will be valuable in assisting the project owners with improving their A/E selection process. Figure 27 illustrates the effectiveness of the current system for selecting the most proper A/E for the project.

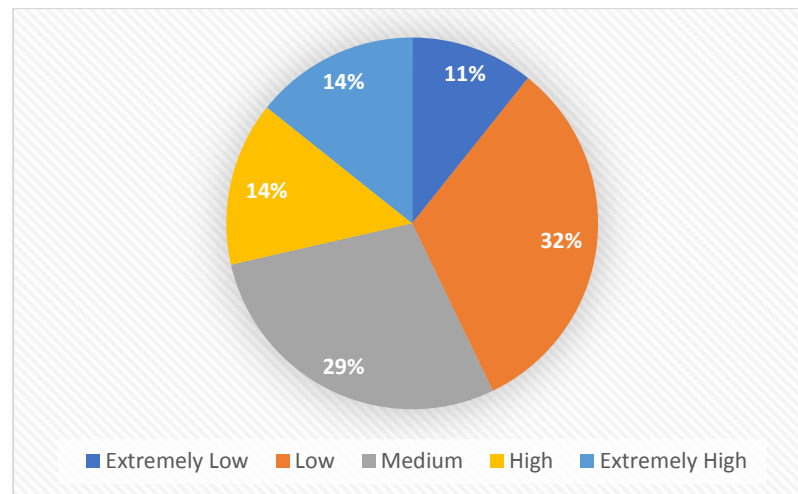


Figure 27. Current A/E Selection System Effectiveness Level

3.6 OWNERS' LEVEL OF SATISFACTION WITH THEIR A/E SELECTION SYSTEM

This section discusses the level of satisfaction project owners have with the performance of their current A/E selection system. Fourteen percent of the respondents were not satisfied with the current system at all, and 29% of the respondents have a very low level of satisfaction with their current system. Eighteen percent of the respondents are somewhat satisfied with their current system. On the other hand, 21% of the respondents have a high level of satisfaction with the current system. Eighteen percent of the respondents were fully satisfied with the current system. These results show that the majority (61%) need to improve their A/E selection system to meet the required level of satisfaction. The main reason for dissatisfaction with the system was due to the majority of A/Es having systems that were not able to meet owners' required level of constraints. As was shown previously, quality, time, and cost constraints were not achieved, with 61%, 57%, and 64% of respondents, respectively. Companies' level of satisfaction with the performance of its current A/E selection system are shown in Figure 28.

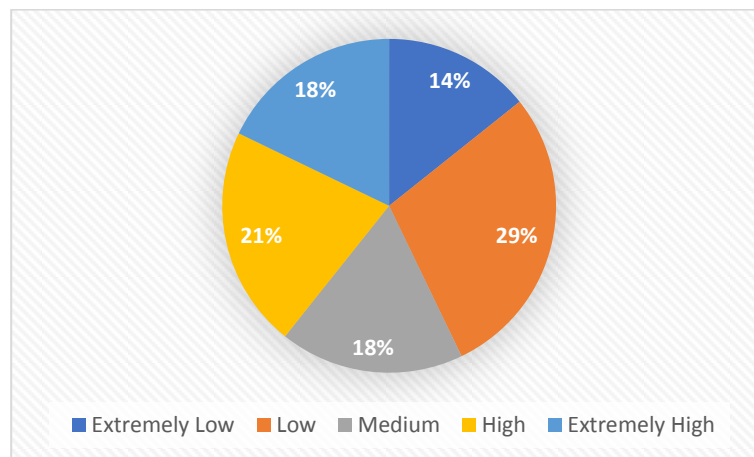


Figure 28. Owners' Satisfaction Level with Their Existing A/E Selection System

4. A/E SELECTION MODEL DEVELOPMENT

The development of the QFD model entails measuring the importance of the criteria and the impact of each criterion on the project constraints: quality, cost, time. The importance and the impact weights will be used to develop the QFD.

4.1 IMPORTANCE OF A/E SELECTION CRITERIA (A/E PERFORMANCE MEASUREMENT)

The results indicated that the majority (96.4%) of respondents consider the A/E technical experience, design quality, staff quality, and bid quality as the highest-rated selection criteria, with relative importance weights of more than 90%. Comparing to the A/E selection criteria in the owner's current system, the owners observed the importance of bid quality, which was not used by any respondents in their current system. This justifies the importance of bid quality in the developed model to measure A/E performance. Moreover, design quality was used by only 7% of the respondents in their current system. Respondents observed the importance of design quality in measuring A/E performance, which provides justification that design quality needs to be used in the developed evaluation model, specifically because design quality is a required service from an A/E and needs to be obtained with the highest quality level. Staff quality is used by 61% of the respondents in their current system and has a high level of importance in measuring A/E performance. This indicates that a higher level of staff quality means a higher level of project quality will be achieved. Technical experience has the highest level of importance (95.7%) and was used in all respondents in their current system. This

justifies that technical experience must be used in the developed model to evaluate A/E performance. Past performance, design service time, project engagement, project context, key designer, and construction estimation quality were highly rated criteria, with an RII of more than 80%. Past performance was a selection criterion used by all the respondents in their current system, which justifies its importance in the research model, as understanding an A/E's previous project performance leads to minimized risk of project failure. A majority of respondents (93%) use key designer in their company's current system during the selection process. This indicates the importance of the key designer during the selection process to achieve the required level of project constraints.

Respondents observed the importance of project engagement, which was not used in any current evaluation system. A higher level of project engagement will lead to the A/E prioritizing the owner's project, which leads to improved service quality. In addition, design service time was used only by 7% of the respondents. This observes the importance of having design service time during the evaluation process, where a delay in providing A/E services will lead to a delay for the whole project. Design, bid, and construction are sequential processes in design-bid-build projects. Construction estimation quality is another important criterion that was used only by 7% of the respondents in their current system. The results of the importance of the construction estimation quality justify the respondents' observation in adding it to the evaluation process, where the highest level of estimation quality will lead to completing a project within budget. It was observed that the design fee has low importance during the selection process and ranked as number eighteen out of twenty-seven criteria. This justifies the importance of selecting and A/E based on the quality of service rather than price. The top ten rated selection criteria have a high influence on project constraints, which will be discussed in the next section. The top

ten criteria will be used in the research model to evaluate A/E performance. There were other criteria that had a medium importance between 70% to less than 80%, which includes implementation of Saudi building code, reputation, number of years in business, customer satisfaction, current workload, specialty designing services, references, design fee, flexibility to suggested design changes, and firm stability. There will be a need to study the influence of these criteria on the project constraints in order to test their influence on project constraints in selecting the most important criteria to be used in the developed model. The influence of the criteria on the project constraints will be discussed on the next section.

A/E office location, percentage of outsourcing work, and nationality of A/E ownership were the lowest-rated criteria. Percentage of outsourcing was used by only 14% of respondents and has an importance index of 52%. A/E office location and nationality of A/E ownership were used by 7% of respondents during their evaluation process and have RII of 56% and 47%, respectively. This justifies that these criteria shouldn't be used during the evaluation process where the other criteria need to be properly evaluated in order to select the most proper A/E.

The RII for the importance of A/E selection criteria is shown in Table 4.

TABLE 4. RII of Importance of A/E Selection Criteria

Sr	Criteria	Frequency					Mean	Standard Deviation	RII
		1	2	3	4	5			
1	Technical Experience	0	0	1	4	23	4.785714	0.498675	0.957143
2	Design quality	0	0	2	9	17	4.535714	0.637248	0.907143
3	Staff Quality	0	0	1	12	15	4.5	0.57735	0.9
4	Bid Quality	0	0	1	12	15	4.5	0.57735	0.9
5	Past Performance	0	1	3	7	17	4.428571	0.835711	0.885714
6	Design Service Time	0	0	3	10	15	4.428571	0.690066	0.885714
7	Project Engagement	0	0	2	12	14	4.428571	0.634126	0.885714
8	Project Context	0	1	5	8	14	4.25	0.887151	0.85
9	Key Designer	0	1	4	11	12	4.214286	0.832539	0.842857
10	Construction Estimation Quality	1	0	2	14	11	4.214286	0.875897	0.842857
11	Implementation of Saudi Building Code	0	5	7	6	10	3.75	1.142609	0.75
12	Reputation	1	3	5	13	6	3.714286	1.049061	0.742857
13	Number of Years in Business	0	3	6	15	4	3.714286	0.854493	0.742857
14	Customer Satisfaction	0	5	8	6	9	3.678571	1.123934	0.735714
15	Current Workload	0	2	9	15	2	3.607143	0.737327	0.721429
16	Specialty Designing Services	1	6	3	11	7	3.607143	1.196887	0.721429
17	References	2	0	10	11	5	3.607143	1.030616	0.721429
18	Design Fee	0	3	13	6	6	3.535714	0.961563	0.707143
19	Flexibility to Suggested Design Changes	1	5	7	9	6	3.5	1.13855	0.7
20	Firm Stability	1	4	10	6	7	3.5	1.13855	0.7
21	Firm Capacity	1	8	5	9	5	3.321429	1.188013	0.664286
22	Problem Solving	4	4	5	9	6	3.321429	1.362285	0.664286
23	Financial Standing	2	5	9	7	5	3.285714	1.181874	0.657143
24	Constructability Services	9	0	4	10	5	3.071429	1.561779	0.614286
25	A/E Office Location	3	9	9	4	3	2.821429	1.156418	0.564286
26	Percentage of Outsourcing Work	8	4	9	5	2	2.607143	1.286375	0.521429
27	Nationality of A/E Ownership	10	8	3	4	3	2.357143	1.393484	0.471429

4.2 INFLUENCE OF SELECTION CRITERIA ON PROJECT CONSTRAINTS

The A/E selection criteria has different levels of influence on project quality, time, and cost constraints. The top ten most important criteria discussed previously will be used during the selection evaluation process. This section will discuss the influence of the criteria and the additional criteria that need to be added to the research model.

The statistical analysis for the influence of selection criteria on the project quality constraint is illustrated in Table 5.

TABLE 5. Influence of Selection Criteria on Project Quality Constraint

Sr	Criteria	Frequency					Mean	Standard Deviation	RII
		1	2	3	4	5			
1	Technical Experience	0	0	3	7	18	4.535714	0.692935	0.907143
2	Design quality	0	1	3	8	16	4.392857	0.831745	0.878571
3	Staff Quality	0	1	3	12	12	4.25	0.799305	0.85
4	Past Performance	0	2	3	12	11	4.142857	0.890871	0.828571
5	Key Designer	1	0	6	10	11	4.071429	0.978607	0.814286
6	Design service Time	0	1	7	10	10	4.035714	0.881167	0.807143
7	Construction estimation quality	1	2	3	11	11	4.035714	1.070899	0.807143
8	Project Engagement	0	2	5	12	9	4	0.902671	0.8
9	Bid Quality	1	3	2	12	10	3.964286	1.104943	0.792857
10	Project Context	2	2	1	14	9	3.928571	1.152407	0.785714
11	Number of years in business	1	3	9	13	2	3.428571	0.920087	0.685714
12	Specialty designing services	1	8	4	9	6	3.392857	1.227442	0.678571
13	Current Workload	2	4	7	12	3	3.357143	1.095928	0.671429
14	Implementation of Saudi Building Code	1	3	12	10	2	3.321429	0.904866	0.664286
15	Customer Satisfaction	2	6	5	12	3	3.285714	1.150109	0.657143
16	Firm Capacity	3	4	7	10	4	3.285714	1.212806	0.657143
17	Problem Solving	1	4	9	14	0	3.285714	0.854493	0.657143
18	Flexibility to suggested design changes	2	6	5	14	1	3.214286	1.066567	0.642857
19	Reputation	3	7	4	12	2	3.107143	1.196887	0.621429
20	Financial Standing	6	5	5	8	4	2.964286	1.400586	0.592857
21	Constructability services	8	3	3	10	4	2.964286	1.502643	0.592857
22	Firm Stability	2	8	8	9	1	2.964286	1.035737	0.592857
23	References	4	6	6	12	0	2.928571	1.119807	0.585714
24	Design fee	5	9	7	4	3	2.678571	1.248809	0.535714
25	Percentage of outsourcing work	7	7	4	8	2	2.678571	1.334821	0.535714
26	A/E Office Location	10	7	5	6	0	2.25	1.174576	0.45
27	Nationality of A/E Ownership	13	4	6	4	1	2.142857	1.268253	0.428571

The results indicate that the ten most important selection criteria are ranked as the top ten criteria that have the highest influence on the project quality constraints. This justifies the importance of having the same selection criteria in order to achieve the required level of project quality. Additional criteria that have a high influence on the quality constraints include number of years in business, specialty designing services, and current workload. This justifies the importance of years in business to obtain the required level of technical experience. In addition, specialty designing service was evaluated with an importance index of 67.7% on quality constraints. This indicates that if an A/E office provide various design services, such as architectural, civil, mechanical, and electrical, then their design services will be of better quality. The more design services provided in-house, the more controlling they are on the design quality. Moreover, current workload was evaluated with an RII of 67%. This justifies the impact of designer current workload in the project quality, where overwhelmed designers will have more design errors that affect the project quality.

For the project time and cost constraints, nine out of the ten most important selection criteria have the top influence on the project schedule, and bid quality was not in the top ten. Current workload has more influence on the project schedule than the bid quality. This justifies the importance of having the current workload for evaluating A/E performance in the research model. Specialty designing services was ranked number thirteen for influence on the time constraint. This provides justification to add it to the research evaluation model. The statistical analysis of the selection criteria's influence on the project time constraint is shown in Table 6.

TABLE 6. Influence of Selection Criteria on Project Time Constraint

Sr	Criteria	Frequency					Mean	Standard Deviation	RII
		1	2	3	4	5			
1	Technical Experience	0	2	1	9	16	4.392857	0.875142	0.878571
2	Design service Time	0	2	3	8	15	4.285714	0.93718	0.857143
3	Design quality	0	1	4	11	12	4.214286	0.832539	0.842857
4	Past Performance	1	1	3	11	12	4.142857	1.007905	0.828571
5	Staff Quality	2	1	3	10	12	4.035714	1.170063	0.807143
6	Project Context	0	2	6	9	11	4.035714	0.961563	0.807143
7	Project Engagement	1	2	3	12	10	4	1.054093	0.8
8	Key Designer	1	4	2	9	12	3.964286	1.2013	0.792857
9	Construction estimation quality	0	3	7	10	8	3.821429	0.983327	0.764286
10	Current Workload	1	1	7	15	4	3.714286	0.89679	0.742857
11	Problem Solving	0	3	9	12	4	3.607143	0.875142	0.721429
12	Firm Capacity	0	8	3	12	5	3.5	1.105542	0.7
13	Specialty designing services	1	8	3	11	5	3.392857	1.196887	0.678571
14	Flexibility to suggested design changes	2	5	5	13	3	3.357143	1.129218	0.671429
15	Number of years in business	0	8	8	8	4	3.285714	1.049061	0.657143
16	Bid Quality	2	6	6	11	3	3.25	1.142609	0.65
17	Firm Stability	4	5	7	9	3	3.071429	1.245096	0.614286
18	Customer Satisfaction	3	7	6	10	2	3.035714	1.170063	0.607143
19	Percentage of outsourcing work	4	7	6	7	4	3	1.30526	0.6
20	Implementation of Saudi Building Code	4	6	8	7	3	2.964286	1.231745	0.592857
21	Financial Standing	4	7	8	7	2	2.857143	1.177388	0.571429
22	Reputation	4	9	7	7	1	2.714286	1.117442	0.542857
23	Constructability services	9	4	3	10	2	2.714286	1.436486	0.542857
24	A/E Office Location	4	11	5	5	3	2.714286	1.24297	0.542857
25	References	6	6	6	10	0	2.714286	1.181874	0.542857
26	Design fee	6	8	7	5	2	2.607143	1.227442	0.521429
27	Nationality of A/E Ownership	13	8	0	5	2	2.107143	1.370031	0.421429

For the influence of selection criteria on the project cost constraint, design fee has slightly more importance than bid quality on project cost. As discussed, for the importance of A/E selection criteria, the design fees have a low importance for evaluating A/E performance. This justifies the importance of including bid quality during the A/E evaluation process. The statistical analysis is illustrated in Table 7.

TABLE 7. Influence of Selection Criteria on Project Cost Constraint

Sr	Criteria	Frequency					Mean	Standard Deviation	RII
		1	2	3	4	5			
1	Design quality	0	3	4	9	12	4.071429	1.015749	0.814286
2	Design service Time	0	3	4	9	12	4.071429	1.015749	0.814286
3	Staff Quality	2	1	4	8	13	4.035714	1.2013	0.807143
4	Technical Experience	2	1	4	9	12	4	1.186342	0.8
5	Past Performance	2	4	4	6	12	3.785714	1.343217	0.757143
6	Key Designer	2	5	4	4	13	3.75	1.404358	0.75
7	Project Context	2	2	7	10	7	3.642857	1.161553	0.728571
8	Construction estimation quality	1	5	4	11	7	3.642857	1.161553	0.728571
9	Project Engagement	2	4	7	6	9	3.571429	1.288944	0.714286
10	Design fee	2	5	7	10	4	3.321429	1.156418	0.664286
11	Bid Quality	3	5	7	9	4	3.214286	1.227981	0.642857
12	Current Workload	0	12	3	10	3	3.142857	1.112697	0.628571
13	Specialty designing services	4	7	3	12	2	3.035714	1.261455	0.607143
14	Firm Capacity	4	8	2	12	2	3	1.276569	0.6
15	Financial Standing	2	11	4	8	3	2.964286	1.2013	0.592857
16	Number of years in business	3	8	9	6	2	2.857143	1.112697	0.571429
17	Percentage of outsourcing work	5	6	7	8	2	2.857143	1.238706	0.571429
18	Customer Satisfaction	6	7	6	6	3	2.75	1.322876	0.55
19	Reputation	5	10	4	7	2	2.678571	1.248809	0.535714
20	Flexibility to suggested design changes	7	7	4	9	1	2.642857	1.282771	0.528571
21	Implementation of Saudi Building Code	5	9	6	7	1	2.642857	1.161553	0.528571
22	Constructability services	10	2	7	7	2	2.607143	1.396803	0.521429
23	Nationality of A/E Ownership	10	6	3	6	3	2.5	1.452966	0.5
24	Problem Solving	7	7	7	7	0	2.5	1.13855	0.5
25	Firm Stability	7	8	7	6	0	2.428571	1.103146	0.485714
26	A/E Office Location	11	5	5	5	2	2.357143	1.366647	0.471429
27	References	8	9	5	6	0	2.321429	1.123934	0.464286

Thus, the top ten selection criteria for measuring A/E performance include technical experience, design quality, staff quality, past performance, key designer, design service time, construction estimation quality, project engagement, bid quality, and project context. The additional importance criteria include number of years in business, specialty designing services, and current workload, which have importance index between 72% and 74%, bringing the total number of criteria to be used in the research model to thirteen. The influence of the thirteen selection criteria on the project quality, time, and cost constraints are illustrated in Figure 29.

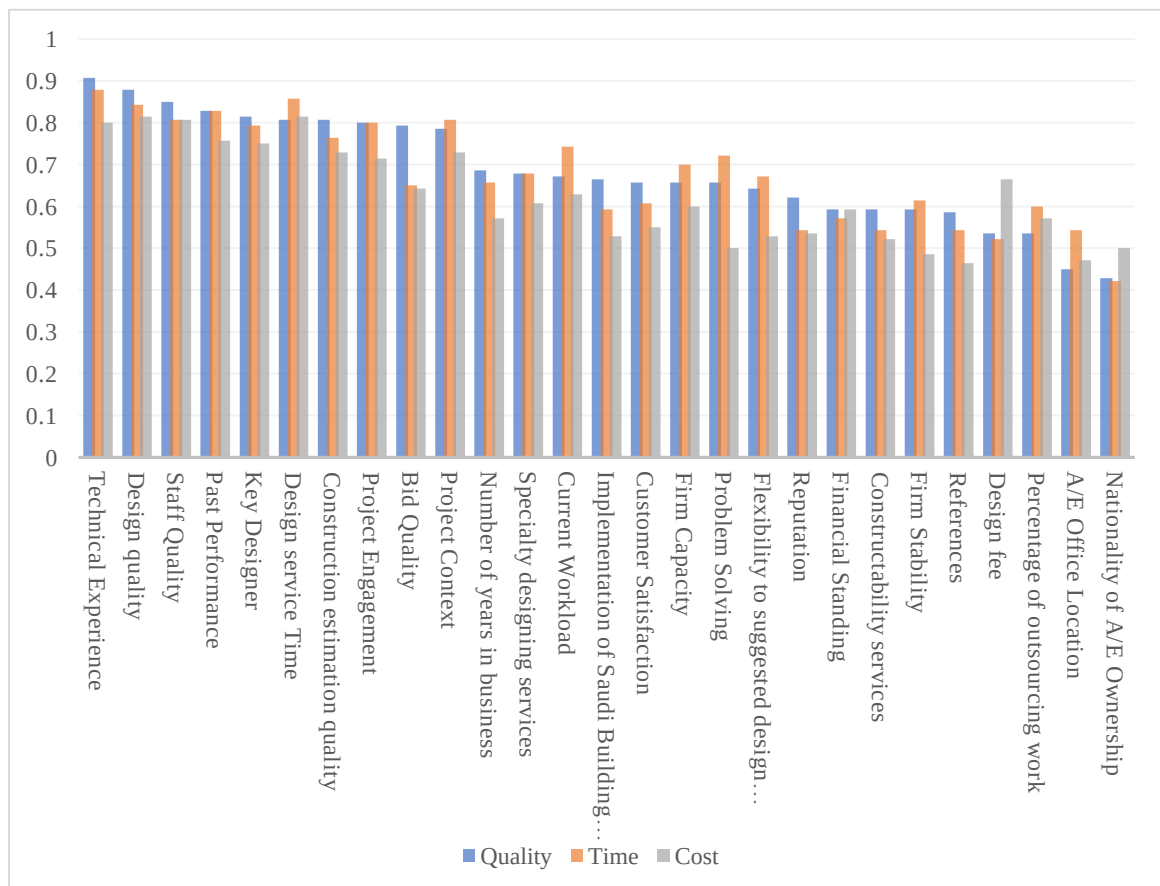


Figure 29. Influence of Selection Criteria on Project Constraints

The top thirteen selection criteria will be used in the QFD model to measure the performance of A/Es in the developed selection process. The influence of these selection criteria is shown in Figure 30.

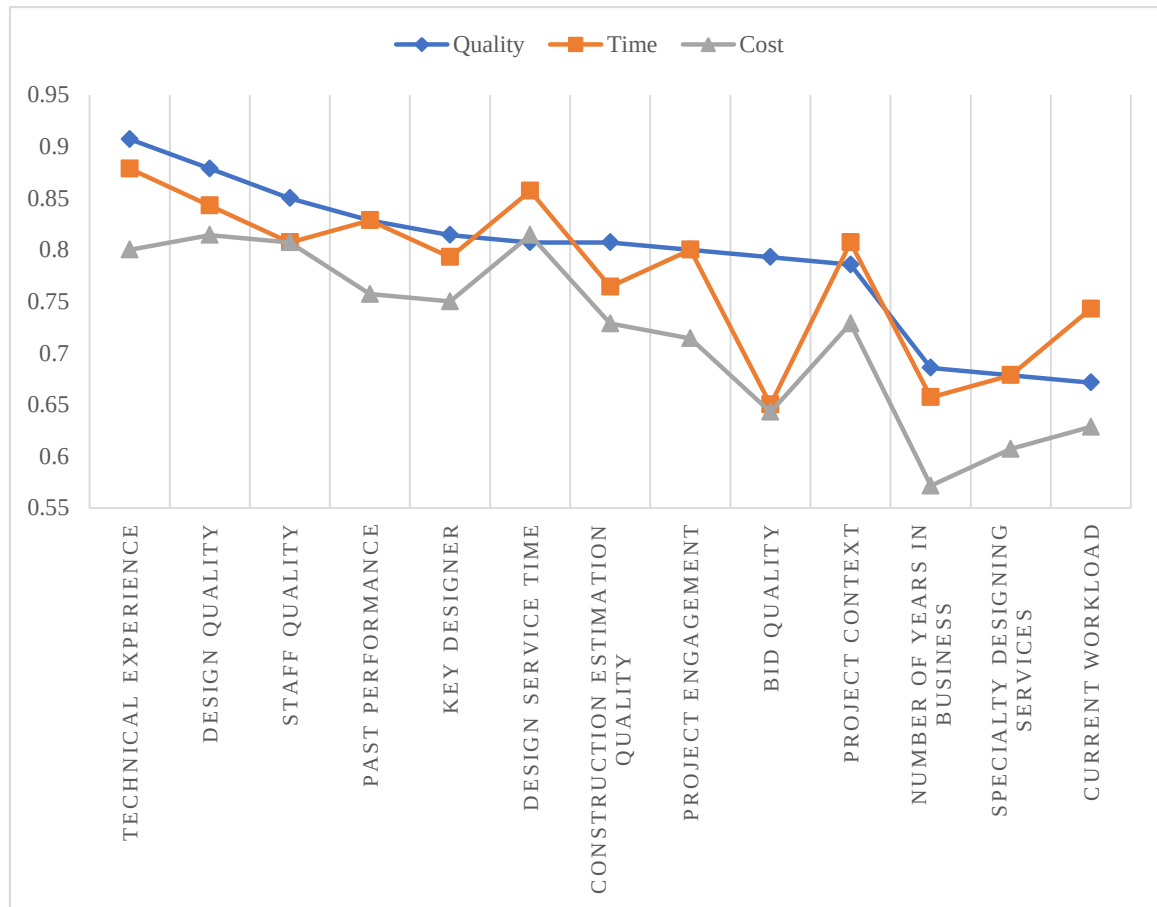


Figure 30. Influence of Top Selection Criteria on Project Constraints

Technical experience has the highest influence on project quality and time constraints, and the highest importance for measuring A/E performance. This justifies the importance of selecting an expert A/E to complete the project on schedule and as per the desired quality. The results justify that design quality has a high effect on the quality and time constraints. It has a higher effect on the project cost than technical experience, where the quality design will lead to less repeated work, additional contractor variation orders, lost materials costs, etc., which can lead to increased project costs. It was observed that staff quality has the highest effect on the project quality constraint. It has almost the same effect on the project time and cost constraints as well. Past performance also has the same high influence on the quality and time constraints and a high influence on the project budget, where the owner can check how the costs have overrun in the A/E's previous projects.

The key designer will be the leader in completing the project as per the desired constraints. The key designer has a very high influence on the project quality, as he will be the leader to identify the desired project overall quality. Also, he has a very high influence on the project time to assure that the project schedule is realistic and on track as per the schedule. Also, the key designer has a high influence on the project cost, as he is the leader for identifying the most proper economical design instead of creating expensive and complicated drawings. Design service time has the highest influence on the project schedule. In design-bid-build projects, the owners will not be able to start the project's bidding until the complete design package is fully prepared by A/E. That explains clearly why the design service time has the highest influence on the project time constraints. Also, it has almost the same influence on the quality and cost constraints.

Construction estimation quality has a very high influence on the quality, time, and cost constraints. It is very important to have an A/E with the highest level of estimation accuracy in order to reduce the risk in resource and material availability so that contractor can finish the work on schedule. Also, a low level of estimation accuracy will lead to cost overrun if the estimated quantity was very low. Moreover, if the estimated quantity was too high, this will lead the contractor to request an increase for the unit price due to quantity changes. Project engagement has the highest influence on the project quality and time. If an A/E gives the highest priority level to the owner's project, that will minimize the risk of design errors and provide the highest level of design quality. Also, this will give the highest priority to the owner for completing the project within the service time.

Bid quality has the highest influence on the project quality. It will assure that the A/E has a full understanding of the owner's required project scope. It has almost the same effect on time and cost constraints. Project context is also a very important selection criteria, as it will assure that the A/E has previously worked with the same types of projects and clearly understands the project environment. This is why it has the highest influence on the project schedule. The A/E will have learned from previous projects how to finish projects faster and avoid previous mistakes. It also has a very high influence on the project quality because the A/E will have learned from previous projects how to avoid previous mistakes and errors.

Number of years in business has a very high effect on the project quality, as more years leads to more technical experience. Specialty designing services provided by the A/E has the highest influence on the project quality and time constraints. If the A/E provides different designing services, such as architectural, civil, electrical, and mechanical design services, this will ensure that A/E provides full design services that link to each other.

Also, it will minimize the service time, which will minimize the risk of delays. Current workload has the highest effect on the project time constraints. If the A/E is overwhelmed, this will lead to a delay in the project design service.

Now, all the required data are available in order to develop the QFD model. The collected data, which includes the selection criteria, importance of selection criteria, and influence of selection criteria on the project quality, time, and cost constraints, will be used in the upcoming section to develop the QFD research model.

5. DEVELOP THE QFD MODEL

As stated in the research methodology, developing the QFD model consists of five steps, as shown in Figure 8. The developed QFD model was developed through the following steps.

- 1. Step 1: Identify the Data Matrix Elements:** The data matrix was developed with the following:
 - a. List of project constraints (WHATs), including quality, time, and cost.
 - b. List of selection criteria (HOWs), including the most important selection criteria that have the highest influence on the project constraints. The selection criteria that will be used in the developed model were the thirteen top-ranked criteria identified in the previous section.
 - c. The importance weight of selection criteria (IHi). The rank of the most important criteria with their RII are illustrated in Table 8.

TABLE 8. QFD Selection Criteria

		Importance
	Criteria	
1	Technical Experience	0.95714286
2	Design quality	0.90714286
3	Staff Quality	0.9
4	Past Performance	0.88571429
5	Key Designer	0.84285714
6	Design service Time	0.88571429
7	Construction estimation quality	0.84285714
8	Project Engagement	0.88571429
9	Bid Quality	0.9
10	Project Context	0.85
11	Number of years in business	0.74285714
12	Specialty designing services	0.72142857
13	Current Workload	0.72142857

This step requires calculating the adjusted weight of each selection criteria for the thirteen selection criteria based on importance. The importance weight of the selection criteria (%) was calculated using the following formula:

$$\text{importance weight of selection criteria } (IH_i) = \frac{RII\ HOW_i}{\sum_{j=1}^n RII\ HOW_i} * 100 \quad (6)$$

The total weight for importance of selection criteria was calculated as:

$$\sum_{j=1}^n RII\ HOW_i = 11.04286$$

The importance weight (IH_i) for each selection criteria were calculated as illustrated in Table 9.

TABLE 9. QFD Model Selection criteria (HOW) and Importance Weight (IHj)

		IH
	Criteria	i%
1	Technical Experience	8.6
		7
2	Design Quality	8.2
		1
3	Staff Quality	8.1
		5
4	Past Performance	8.0
		2
5	Key Designer	7.6
		3
6	Design Service Time	8.0
		2
7	Construction Estimation Quality	7.6
		3
8	Project Engagement	8.0
		2
9	Bid Quality	8.1
		5
10	Project Context	7.7
		0
11	Number of Years in Business	6.7
		3
12	Specialty Designing Services	6.5
		3
13	Current Workload	6.5
		3

- d. Measure the influence of selection criteria on the project constraints. This step includes the influence of each selection criteria on quality, time, and cost, which were labeled as S1n, S2n, and S3n, respectively. The results for the influence of each were measured based on RII value, which were analyzed in the previous section. The RII of the influence of each selection criteria on the constraints quality, time, and cost (S1n, S2n, and S3n) are illustrated in Table 10.

TABLE 10. QFD Model Selection Criteria (HOW) Influence on Project Constraints

		Project Constraints		
	Criteria	Quality	Time	Cost
1	Technical Experience	0.907142857	0.878571429	0.8
2	Design Quality	0.878571429	0.842857143	0.814285714
3	Staff Quality	0.85	0.807142857	0.807142857
4	Past Performance	0.828571429	0.828571429	0.757142857
5	Key Designer	0.814285714	0.792857143	0.75
6	Design Service Time	0.807142857	0.857142857	0.814285714
7	Construction Estimation Quality	0.807142857	0.764285714	0.728571429
8	Project Engagement	0.8	0.8	0.714285714
9	Bid Quality	0.792857143	0.65	0.642857143
10	Project Context	0.785714286	0.807142857	0.728571429
11	Number of Years in Business	0.685714286	0.657142857	0.571428571
12	Specialty Designing Services	0.678571429	0.678571429	0.607142857
13	Current Workload	0.671428571	0.742857143	0.628571429

Now, all the inputs are available to develop the data matrix. The data matrix includes the weighted importance of selection criteria (Table 9) and the influence of the selection criteria on project constraints (Table 10). The data matrix will be used as the input for the calculations during the evaluation process. The data matrix is shown in Table 11.

TABLE 11. QFD Model Data Matrix

		Selection Criteria												
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload
		8.67	8.21	8.15	8.02	7.63	8.02	7.63	8.02	8.15	7.70	6.73	6.53	6.53
Project Constraints	Quality	0.91	0.88	0.85	0.83	0.81	0.81	0.81	0.80	0.79	0.79	0.69	0.68	0.67
	Time	0.88	0.84	0.81	0.83	0.79	0.86	0.76	0.80	0.65	0.81	0.66	0.68	0.74
	Cost	0.80	0.81	0.81	0.76	0.75	0.81	0.73	0.71	0.64	0.73	0.57	0.61	0.63

2. Step 2: Evaluation of A/E in QFD Process Matrix: The process matrix identified the evaluation process that includes the variables needing to be input by the evaluator. Each A/E needs to be evaluated in a separate matrix. The input variables include the following.

- a. The importance of each project constraints (What) to the owner (PWi): Every project owner has a different level of importance for each constraint. The evaluator is required to input the importance value for quality, time, and cost based on the project owner requirements. The scale of importance for each project constraint will be 0 (without importance), 0.2 (lowest importance), 0.4

(low importance), 0.6 (medium importance), 0.8 high importance, and 1 (highest importance). The value for the importance of each project constraint needs to be the same value in each A/E process matrix.

- b. The A/E performance evaluation (PHi): This process includes the inputs for measuring A/E performance in each selection criteria. The A/E performance needs to be measured on a scale between zero and one (0% to 100%). Each A/E will be evaluated in a separate process matrix. The process matrix is shown in Figure 31.

Consultant Name: 

		Selection Criteria														
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload		
Project Constraints	Quality	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Time	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	Cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Please, evaluate the importance of project constraints (PWi)

0	(without importance)
0.2	(lowest importance)
0.4	(low importance)
0.6	(medium importance)
0.8	(high importance)
1	(highest importance)

Please, evaluate the consultant performance on the scale between 0 to 1 (Phi)

Figure 31. QFD Model Process Matrix

3. **Step 3: Calculating the Point Scores (R_{ij}):** Step 3 includes the calculation of each point score by multiplying the values of the data matrix and process matrix. In this step, the point score (R_{ij}) of the intersection between each *WHAT* and *HOW* will be calculated as shown in equation 1.

$$R_{ij} = PW_i \times (IH_i \times PH_i) \times S_{ij} \quad (1)$$

Where:

R_{ij} is the point score for the intersection between *WHAT* and *HOW*

PW_i is the importance of project constraints (*WHAT*) to the owner (step 2)

IH_i is the importance weight of selection criteria (step 1)

PH_i is the A/E performance evaluation (step 2)

S_{ij} is the strength of the interrelationships between $WHAT_i$ and HOW_j (step 1)

4. **Step 4: Calculating the Pre-qualification Score (PS):** The pre-qualification score is calculated by summing the value of point scores (R_{ij}). The pre-qualification score indicates the performance of each consultant. The pre-qualification score for each A/E is calculated as shown in equation 4.

$$PS = \sum_{i=1}^m PSW_i = \sum_{i=1}^n PSH_j \quad (4)$$

5. **Step 5: Calculating the Consultant Pre-qualification Index (CPI) and**

Ranking: The consultant performance index (CPI) identifies the final score

achieved by the A/E. Every consultant will have a CPI score. The CPI for each specific A/E is calculated as shown in equation 5:

$$CPI = \frac{PS}{MaxPS} \quad (5)$$

Where:

PS is the pre-qualification score calculated in equation (4)

MaxPS is the maximum score of pre-qualification that an A/E can achieve where the entire statues of *HOWs* are rated at their highest value (100%).

The A/E with highest CPI score will be the first ranked and recommended to be selected.

6. QFD MODEL VALIDATION

The developed QFD model will be compared and synthesized with the owner's current system they use to evaluate A/Es to be selected for their project. The owner will select one of their design-bid-build projects and use the new format shared with them for the QFD model. Then, the owner will compare the two outcomes.

6.1 QFD MODEL VALIDATION WITH OWNER 1

The QFD model was validated with owner 1. This owner is a private manufacturing company in Dammam, Saudi Arabia and has more than 2500 employees. Owner 1 is a

repetitive builder, and the value of the contract size of the validated project is more than SR100 million. The contract value for the design services was more than SR4 million. Their project was to build a mega project plant by using a design-bid-build delivery system with a quality-based selection system for A/E services. The project owner did not have a prepared list of a prequalified A/E to be invited for their project. There were three A/E offices that they evaluated for their project. The three A/E offices were called Consultant E, Consultant A, and Consultant B due to confidentiality of the companies. Using the owner's existing evaluation system, Consultant E was awarded the project. The QFD model was applied by owner 1 as shown below.

6.1.1 CONSULTANT E

The QFD process matrix needed to be completed by the owner for consultant E. The owner first rated the importance of the project constraints for their project. The project time was the most important and was ranked as the highest importance, which equals a value of one. The project quality was of high importance, as the project needed to be completed at a high level of quality due to the sensitivity of their project. The project cost was ranked as low importance, as the company was more concerned that the project be completed on time. The importance rating for the project quality, time, and cost constraints are shown in Table 12.

TABLE 12. Consultant E Process Matrix

		Selection Criteria														
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload		
		0.85	0.50	0.50	0.75	0.90	0.20	0.60	0.70	0.90	0.90	0.85	0.35	0.80		
Project Constraints	Quality	0.8	5.347	2.887	2.771	3.987	4.475	1.036	2.957	3.593	4.653	4.354	3.137	1.241	2.807	43.25
	Time	1.0	6.473	3.462	3.289	4.984	5.446	1.375	3.500	4.492	4.768	5.592	3.758	1.552	3.882	52.57
	Cost	0.4	2.358	1.338	1.316	1.822	2.061	0.522	1.335	1.604	1.886	2.019	1.307	0.555	1.314	19.44
			14.18	7.69	7.38	10.79	11.98	2.93	7.79	9.69	11.31	11.96	8.20	3.35	8.00	115.25

Then, the owner evaluated consultant E's performance in the project matrix. Consultant E was evaluated for each selection criteria based on his performance. Key designer, bid quality, and project context were the highest-rated selection criteria for consultant E, at 90% for each. The lowest rating was on design service time, where the consultant was rated at 20%. After evaluating consultant E, the points were scored using the formula $R_{ij} = P_{Wi} \times (I_{Hi} \times P_{Hi}) \times S_{ij}$. The calculations for each R_{ij} value are shown in Table 12. The fourth step is to calculate the prequalification score (PS) for consultant E. The prequalification score is calculated using the formula $PS = \sum_{j=1}^m PSW_i = \sum_{j=1}^n PSH_j$. The prequalification score (PS) for consultant E is 115.25. The maximum point score that could be achieved by the consultant equals 171.08. The fifth step is to calculate the consultant performance index (CPI) by dividing the point score (PS) by the maximum point score. The CPI for consultant E equaled 0.6737. The same process will be applied to the other two A/Es to select the consultant with the highest CPI value.

6.1.2 CONSULTANT A

The second consultant is evaluated in a separate process matrix. The same steps implemented with the previous consultant will be implemented with consultant A. The importance of the project constraints will be the same in all A/E process matrices. The project owner will evaluate the performance of consultant A as shown in Table 13.

TABLE 13. Consultant A Process Matrix

		Selection Criteria													
Project Constraints		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload	
		0.70	0.65	0.65	0.65	0.65	0.70	0.40	0.90	0.90	0.35	0.65	0.85	0.90	
	Quality	0.84	4.03	3.75	3.60	2.34	5.63	3.23	2.36	2.51	1.97	1.46	2.53	3.01	5.18
	Time	1.05	3.31	4.50	1.27	4.32	0.93	4.81	2.33	5.77	4.76	2.17	2.87	3.76	4.36
	Cost	0.41	1.94	2.73	1.71	0.57	1.48	1.82	0.89	2.06	1.88	0.78	0.99	1.34	1.47
		11.68	9.99	9.59	9.35	8.65	10.27	5.19	12.46	11.31	4.65	6.27	8.13	9.00	116.55

Project engagement, bid quality, and current workload were the highest-rated performances for consultant A, with 90% for each. Project context was the lowest among all criteria, which was equal to 35%. Design service time was much better compared to consultant E. The prequalification score for Consultant A equaled to 116.55. The calculated CPI for consultant A was 0.6813.

6.1.3 CONSULTANT B

There were three consultants bidding for owner 1's project. Consultant B's performance was evaluated as shown in the process matrix in Table 14.

TABLE 14. Consultant B Process Matrix

		Selection Criteria													
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload	
Quality		0.8	0.95	0.90	0.90	0.90	0.90	0.95	0.80	0.70	0.85	0.70	0.90	0.50	0.70
Time		1.0	7.234	6.231	5.920	5.981	5.446	6.531	4.667	4.492	4.503	4.349	3.979	2.217	3.397
Cost		0.4	2.635	2.408	2.368	2.186	2.061	2.482	1.779	1.604	1.781	1.570	1.384	0.793	1.150
			15.84	13.84	13.28	12.95	11.98	13.93	10.39	9.69	10.68	9.31	8.68	4.78	7.00

Technical experience and design service time were the highest-rated performances for consultant B, with 95%. Also, design quality, staff quality, key designer, and number of years in business were evaluated at 90%. The lowest performance was for specialty designing services, with 50%, most likely because consultant B provides civil and architectural design services. The prequalification score of consultant B was 142.36. The CPI score for consultant B was 0.8321.

6.1.4 COMPARE AND SYNTHESIZE

With the owner's current system, consultant E was awarded the project. By implementing the QFD model, consultant B achieved the highest score and should have

been awarded the project, with a CPI score of 0.8321 compared to consultant E's CPI of 0.6737. The rankings for all the three consultants are shown in Table 15.

TABLE 15. QFD Consultant Rankings for Owner 1's Project

Rank	Consultant	PS	CPI
1	Consultant B	142.36	0.8321
2	Consultant A	116.55	0.6813
3	Consultant E	115.25	0.6737
	Max PS	171.08	

Owner 1 commented that with their current system, they evaluated the A/E based on technical experience, past performance, key designer, bid quality, project context, and specialty designing services. They didn't put any consideration into design quality, staff quality, design service time, or construction estimation quality. The evaluation results for consultant E showed that the major weakness in their current system was in the missing evaluation criteria. The main weaknesses of consultant E were in construction estimation quality (60%), design quality (50%), staff quality (50%), design service time (20%), and specialty designing services (35%). Selecting consultant E with their current system was an improper decision, as commented by the owner. The owner agrees with the QFD model, where the design quality of consultant E was the worst compared to the other two A/Es. That deficiency caused building defects which led to stopping fifty percent of the plant production capacity due to improper load calculations for the period of one year. The owner went on to dispute in court with consultant E claiming lost production and the costs for repairing the building. Also, the construction estimation for consultant E was poor, with an estimation accuracy of 37.5% more than the actual cost, which caused the

contractor to claim a need to change all the unit rate prices due to differences in quality. Moreover, the project time constraint was the highest importance, and the owner was supposed to complete the project as defined by the owner. The agreed design service time to complete the design package was eight months as agreed to with all the consultants. The actual design service time was two years, and the consultant submitted partial drawings to be constructed by the contractor instead of the whole package. This led to a three-year delay for the whole project.

After the failure of consultant E, the owner hired consultant B to complete the project and to do a proper design to correct the poor design quality provided by consultant E. In a comparison of consultants B and E, the QFD model showed the strengths of consultant B in comparison to the weaknesses of consultant E. The strengths of consultant B were in design quality (90%), staff quality (90%), design service time (95%), and construction estimation quality (80%). Consultant E was better in designing cost and project context in comparison to consultant B. Both had the same quality of key designer. The owner agree that they should have measured staff quality, design service time, and construction estimation time, which were not considered in their existing system. Consultant B had a much better staff quality, design quality, and design service time. The owner agreed with the QFD model results, which showed that consultant B should have been hired for their project.

6.2 QFD MODEL VALIDATION WITH OWNER 2

The QFD model was validated with another owner who was called owner 2 due to confidentiality. The second owner is a semi-private firm located in Dammam, Saudi

Arabia. The project owner is a repetitive builder with an average project size of more than SR100 million. The contract value for this project was more than SR100 million for the construction of a main road bridge. The design services value for this project was more than SR4 million. The owner's line of business is management services, and their organization size is between 250 and 500 employees. The project owner has a prepared list of prequalified A/E and uses a price-based selection system. The project owner was to build an infrastructure road and bridge that is considered to be one of the main roads in Dammam. There were three consultants who bid on this project. The three consultants will be called KA, DH, and AM due to confidentiality. KA was the selected A/E for the project using the owner's existing evaluation system. Owner 2 applied the QFD model to compare the results with their current evaluation system. The results of the evaluation by implementing the QFD model are shown in the below subsections.

6.2.1 CONSULTANT KA

Consultant KA was the A/E awarded the project contract. The owner rated the importance of the project constraints and consultant KA's performance as shown in Table 16.

TABLE 16. Consultant KA Process Matrix

Projec	Quality	Selection Criteria													
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload	
		0.90	0.40	0.90	0.90	0.90	0.80	0.30	0.50	0.70	0.90	0.90	0.90	0.90	
←	0.8	5.661	2.310	4.988	4.785	4.475	4.143	1.479	2.567	3.619	4.354	3.321	3.192	3.158	48.05

Time	1.0	6.854	2.770	5.920	5.981	5.446	5.500	1.750	3.208	3.708	5.592	3.979	3.990	4.368	59.07
Cost	0.6	3.744	1.605	3.552	3.279	3.091	3.135	1.001	1.719	2.201	3.028	2.076	2.142	2.217	32.79
		16.26	6.68	14.46	14.05	13.01	12.78	4.23	7.49	9.53	12.97	9.38	9.32	9.74	139.91

The time constraint was the highest importance for this project, as the road and the bridge are on the main road, so this aspect was rated as 1. The project must be completed at a high level of quality, which was rated as 0.8. The project will be funded by the government, and the cost importance was medium and rated as 0.6.

Consultant KA is one of the best A/Es in owner 2's list. The consultant's performance was very high for most of the selection criteria. It was noticed, however, that the construction estimation quality was very poor and was evaluated at 30%. The design quality was also poor and was evaluated at 40%. Project engagement was evaluated at 50%. As stated by the owner, the causes of the poor performance in design quality and construction estimation quality were due to low project engagement. When the consultant KA was awarded this project, he subcontracted the designing work to a smaller A/E. The actual work was done by a small A/E office who had poor design quality and construction estimation. That led to a cost overrun of SR65 million in addition to delays in the project. The prequalification score for consultant KA was 139.91, as shown in Table 16. The maximum PS that can be achieved by an A/E is 185.60. The CPI score for consultant KA was 0.7538.

6.2.2 CONSULTANT DH

Consultant DH is smaller in size compared to consultant KA. Consultant DH has the highest level of engagement on the project, as the project was considered a major one for him. The evaluation of consultant DH is shown in Table 17.

TABLE 17. Consultant DH Process Matrix

		Selection Criteria														
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload		
		0.80	0.70	0.70	0.80	0.80	0.90	0.80	0.90	0.70	0.60	0.60	0.80	0.90		
Project Constraints	Quality	0.8	5.032	4.042	3.879	4.253	3.978	4.661	3.943	4.620	3.619	2.903	2.214	2.837	3.158	49.14
	Time	1.0	6.092	4.847	4.605	5.317	4.841	6.187	4.667	5.775	3.708	3.728	2.652	3.546	4.368	60.33
	Cost	0.6	3.328	2.809	2.763	2.915	2.748	3.527	2.669	3.094	2.201	2.019	1.384	1.904	2.217	33.58
			14.45	11.70	11.25	12.48	11.57	14.38	11.28	13.49	9.53	8.65	6.25	8.29	9.74	143.05

Consultant DH has the highest performance in design service time, project engagement, and the current service time with 90%. These three performance criteria are the main criteria toward completing the project within the required time frame. The lowest performance was with project context and the number of years in business, with 60%. The prequalification score was 143.05, with a CPI equal to 0.7708.

6.2.3 CONSULTANT AM

The project owner's evaluation of consultant AM using the QFD model is shown in Table 18.

TABLE 18. Consultant AM Process Matrix

		Selection Criteria														
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload		
		0.80	0.70	0.60	0.70	0.80	0.90	0.80	0.90	0.80	0.70	0.60	0.70	0.70		
Project Constraints	Quality	0.8	5.032	4.042	3.325	3.722	3.978	4.661	3.943	4.620	4.136	3.387	2.214	2.483	2.456	48.00
	Time	1.0	6.092	4.847	3.947	4.652	4.841	6.187	4.667	5.775	4.238	4.349	2.652	3.103	3.397	58.75
	Cost	0.6	3.328	2.809	2.368	2.551	2.748	3.527	2.669	3.094	2.515	2.355	1.384	1.666	1.725	32.74
			14.45	11.70	9.64	10.92	11.57	14.38	11.28	13.49	10.89	10.09	6.25	7.25	7.58	139.48

The highest performance for consultant AM is in design service time and project engagement, which were evaluated at 90%. The lowest performance was in staff quality and number of years in business. The prequalification score for consultant A/E was 139.48, with a CPI score equal to 0.7515.

6.2.4 COMPARE AND SYNTHESIZE

The project time constraint was the highest importance, as the project must be completed on schedule because it is a main road and bridge in Dammam. The rating for the project time constraint was 1. The project was supposed to be completed with a high level of quality, which was rated as 0.8. The project cost had a medium importance, which

was rated as 0.6. The three consultants were supposed to work toward achieving the owner's required constraints. The three consultants' rankings using the QFD model are shown in Table 19.

TABLE 19. Consultant Rankings for Owner 2's Project

QFD Model			
R ank	Consultant	PS	CPI
1	DH	143.0 5	0.77 08
2	KA	139.9 1	0.75 38
3	AM	139.4 8	0.75 15
		185.6	
		Max PS	0

The A/E who was awarded the project using the owner's existing evaluation system was consultant KA. The criteria used in that system included technical experience, past performance, project context, design fee, and design service time. Consultant KA's project engagement was low and the project was a low priority, and as a result it was subcontracted to a smaller sized A/E who did the actual work. After completing the design, the design was bid on and awarded to a contractor. The design quality of the project was very poor and could not be constructed. This led to a delay in the project time because a design review was required to be done by a third party. Consultant KA agreed that there was a major design error, and the project need to be redesigned. The new design

led to cost overrun of SR65 million. That led to dispute between the owner and consultant KA, where the owner claimed for the cost overrun. Moreover, the project time was rated as the highest importance, and there was a project delay of two years. The owner mentioned that they were supposed to have project engagement during the evaluation process, as the consultant had good design quality, but since the project was the lowest priority, he subcontracted the work to a lower quality designer. The main causes of project failure were the poor performance of consultant KA in design quality (40%), construction estimation quality (30%), and project engagement (50%). In comparison to consultant DH, which was selected by the new model, the evaluation criteria clarified the main causes of consultant KA's failure. Consultant DH's strengths were shown in design quality (70%), construction estimation quality (80%), and project engagement (90%). The owner agreed that consultant DH should have been awarded the project, where the project engagement was a high priority. If consultant DH had been awarded the contract, he would have put all the effort into completing the project per the owner's requirements. The project would have been a major project for consultant DH and was a minor project to consultant KA.

6.3 QFD MODEL VALIDATION WITH OWNER 3

Owner 3 is a semi-private organization located in Jubail, Saudi Arabia and has more than 2500 employees. The owner is a repetitive builder, and their line of business is utilities services. The contract size is more than SR100 million, and the contract value for the A/E's services is more than SR4 million. The project was to build a new head office for the company. The selection system that was used to select the A/E was a price-based

selection system. The owner has a prequalified list of A/Es to be invited for bidding.

There were three consultants being considered for their project, who are called consultant A, consultant B, and consultant C due to confidentiality. Owner 3 has their evaluation system where the A/E must achieve an evaluation score of 70% or more in their technical evaluation, otherwise the A/E will be rejected. After the consultant achieves the minimum score, the A/E will be selected based on the lowest price. The main drive for selecting an A/E is based on the lowest price regardless the archived score in their evaluation.

Consultant B was awarded the project. The QFD model was applied by Owner 3 to compare between the two evaluation models.

6.3.1 CONSULTANT A

The owner rated the project cost to be within budget as the highest importance among the project constraints. The project quality was rated as high importance at 0.8. The time constraint was rated at 0.6 with medium importance. The rating of the project constraints importance and consultant A's evaluation are shown in Table 20.

TABLE 20. Consultant A Process Matrix

Project Constraints		Selection Criteria													
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload	
		0.80	0.90	0.75	0.70	0.80	1.00	0.90	0.60	0.75	0.80	0.50	0.70	0.65	
Quality	0.8	5.032	5.196	4.157	3.722	3.978	5.179	4.436	3.080	3.877	3.871	1.845	2.483	2.281	49.14
Time	0.6	3.655	3.739	2.960	2.791	2.905	4.125	3.150	2.310	2.384	2.982	1.326	1.862	1.893	36.08

Cost	1.0	5.547	6.020	4.934	4.251	4.580	6.531	5.005	3.437	3.929	4.486	1.922	2.777	2.669	56.09
		14.23	14.96	12.05	10.76	11.46	15.84	12.59	8.83	10.19	11.34	5.09	7.12	6.84	141.31

Consultant A has the best performance with the highest performance in design service time. He has excellent performance in design quality and construction cost estimation as well. This A/E has the lowest number of years in the business among the three consultants but has very good technical experience. The project engagement is quite low, as he is relatively busy with other projects. The prequalification score of consultant A is 141.31, with a CPI equal to 0.7706.

6.3.2 CONSULTANT B

Consultant B has the lowest rating in the owner's existing system, but he passed the minimum score of 70%. He quoted with the minimum price and was awarded the project. The evaluation of consultant B is shown in Table 21.

TABLE 21. Consultant B Process Matrix

		Selection Criteria														
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload		
		0.75	0.80	0.60	0.75	0.70	0.80	0.85	0.60	0.70	0.65	0.60	0.70	0.80		
Project Constraints	Quality	0.8	4.718	4.619	3.325	3.987	3.480	4.143	4.189	3.080	3.619	3.145	2.214	2.483	2.807	45.81
	Time	0.6	3.427	3.323	2.368	2.991	2.542	3.300	2.975	2.310	2.225	2.423	1.591	1.862	2.329	33.67

Cost	1.0	5.201	5.351	3.947	4.555	4.007	5.225	4.727	3.437	3.668	3.645	2.306	2.777	3.285	52.13
		13.34	13.29	9.64	11.53	10.03	12.67	11.89	8.83	9.51	9.21	6.11	7.12	8.42	131.61

The staff quality was the lowest compared to the other consultants and was evaluated as 60%. The technical experience and the key designer performance were lower than the other two consultants as well. Consultant B's project engagement was low, but he doesn't have a high current load with other projects. The prequalification score was 131.61, with a CPI equal to 0.7177.

6.3.3 CONSULTANT C

The evaluation of the performance for consultant C is shown in Table 22.

TABLE 22. Consultant C Process Matrix

Project Constraints	Selection Criteria															
		Technical Experience	Design quality	Staff Quality	Past Performance	Key Designer	Design service Time	Construction estimation quality	Project Engagement	Bid Quality	Project Context	Number of years in business	Specialty designing services	Current Workload		
		0.90	0.85	0.75	0.80	0.90	0.85	0.95	0.80	0.85	0.80	0.85	0.80	0.85		
	Quality	0.8	5.661	4.908	4.157	4.253	4.475	4.402	4.682	4.107	4.394	3.871	3.137	2.837	2.983	53.87
	Time	0.6	4.112	3.531	2.960	3.190	3.268	3.506	3.325	3.080	2.702	2.982	2.255	2.128	2.475	39.51
Cost	1.0	6.241	5.686	4.934	4.858	5.152	5.551	5.283	4.583	4.453	4.486	3.267	3.173	3.490	61.16	
		16.01	14.12	12.05	12.30	12.89	13.46	13.29	11.77	11.55	11.34	8.66	8.14	8.95	154.54	

Consultant C has the highest performance in construction estimation quality, which was evaluated at 95%. In addition to that, he has the best performance compared to the

other consultants in technical experience and key designer, which was considered as a main driver toward completing the project on budget. The lowest performance was in staff quality, which was evaluated at 75%, which was the highest evaluation of staff quality between the three consultants. The prequalification score for consultant C was 154.54, with a CPI equal to 0.8428. Consultant C should have been awarded the project by implementing the QFD model.

6.3.4 COMPARE AND SYNTHESIZE

The project cost constraint was the highest importance for owner 3's project, which was rated with 1. The quality constraint was of high importance and was rated at 0.8. The project time constraint was of medium importance, as the project could be extended to an acceptable time frame that should not have exceeded six months. The owner commented that their current evaluation system has some common evaluation criteria, such as technical experience, past performance, staff quality, and bid quality. The A/E must reach the minimum acceptable score of 70%. If the A/E reaches the minimum score of 70%, the lowest price bidder will be selected automatically. The major problem was that they will not select the A/E with the highest quality in order to maximize the probability of reaching the project's required constraints. Consultant B was awarded the project, where he achieved the minimum required score and he was the lowest price bidder. The scoring and ranking using QFD model for the three consultants are shown in Table 23.

TABLE 23. Consultant Rankings for Owner 3's Project

QFD Model			
R ank	Consultant	PS	CPI

1	Consultant C	154.5	0.84
		4	28
2	Consultant A	141.3	0.77
		1	06
3	Consultant B	131.6	0.71
		1	77
		183.3	
Max PS		7	

As shown in the results, consultant B had the lowest performance among the three consultants. Consultant C should have been hired because he achieved the highest score. The weaknesses of consultant B were in project engagement (60%), project context (65%), and in number of years in business (60%), which were not evaluated in the owner's current evaluation system. Comparatively, consultant C had a better performance in project engagement, project context, and years in business with a result of 80%, 80%, and 85%, respectively. The QFD model has a wider range of evaluation criteria that assisted the owner in a better selection during the evaluation period in comparison to their current system. The project manager agreed with the results and commented that they believe the project could have much better results if consultant C had been hired. The problem with consultant B was that the project priority was very low, which led to low project quality. There was a cost overrun by 15% in the project, which was considered to be acceptable. Regarding the project schedule, there was a delay in the project schedule by 45% of the project required time. The owner believes that the project quality and time constraints could be achieved if consultant C had been assigned to the project, and they agree with the QFD model results.

6.4 SOFTWARE

For the ease of use, software was developed with an intuitive and straightforward interface. The interface guides the user through the evaluation process and offers instruction at each stage. In the first stage, the interface will prompt the user to enter the number of A/E offices to be evaluated. The second stage will ask the user to input the importance of each project constraint (quality, cost, and time). Then, the interface guides the user on the evaluation process for all criteria for each A/E office to produce a final evaluation based on the calculations and the process of the model. The model software can be downloaded online (<https://archgalleries.com/en/qfd-model-for-a-e-selection-based-in-qualification-and-project-constraints/>).

CHAPTER 5: SUMMARY, FINDINGS, AND RECOMMENDATIONS

This chapter provides a summary of the research and the findings. The research conclusion will be summarized in addition to the recommendations. The final section will provide recommendations for future studies.

1. SUMMARY OF THE STUDY

The A/E selection process is defined as the method used to select the best architectural engineer to provide design or engineering services in a design-bid-build project delivery system. Proper selection of an A/E can lead to fulfilment of a project's required level of quality, time, and cost.

The main objectives of the research are developing an A/E selection system based on qualification criteria and project constraints. The research specifically focused on six objectives: 1) determine the current A/E selection system to understand the existing market; 2) determine the owners' selection criteria; 3) determine the project constraints; 4) measure the importance of A/E selection criteria to measure the A/E's performance; 5) measure the influence of the selection criteria on the project constraints; 6) develop an A/E selection system based on qualification criteria and project constraints to assist the owner in proper A/E selection.

The data was collected using a web survey, email, teleconference meeting, and personal visits with participants from the sample of twenty-eight large industrial sector respondents in the eastern province in Saudi Arabia. The data was analyzed using statistical methods and computer software for proper data visualization and observation to

understand the owners' current systems and evaluation processes and to ensure proper measurements in the research evaluation model. The findings will be discussed in the next section.

1.1 FINDINGS

1.1.1 MAJOR FINDINGS

The major research findings are listed and summarized below.

- The majority of large-sized owners have lists of prequalified A/E offices from which they select potential A/E offices for designing new projects.
- The large-size owners use different criteria for selecting potential A/Es from a prequalified list. Some (32%) select potential A/Es based on A/E design specialization, type of project, and A/E past experience, while others (25%) select potential A/Es based on design specialization only.
- The large-sized owners use different A/E selection systems. Some (36%) use a price-based selection system, some (21%) use a quality-based system, some (18%) use best value, some (11%) use fixed budget/best technical value, and some (14%) use a weighted criteria A/E selection system.
- The majority of the large-sized owners are not satisfied with their current A/E selection systems and consider them ineffective in achieving the required project constraints, including quality, time, and cost.
- The majority of large-size owners use technical experience, the A/E's past performance, customer satisfaction, and key designer staff quality criteria in their current A/E selection systems.

- Very few large-sized owners use A/E office location, constructability services, construction estimation quality, current workload, design quality, design service time, firm stability, flexibility to suggested design changes, implementation of Saudi building code, nationality of A/E ownership, problem solving, and specialty designing services in their current A/E selection systems.
- The project constraints that are used to define large-size owners' requirements are the quality, the time, and the cost.
- Technical experience, design quality, staff quality, bid quality, past performance, design service time, project engagement, project context, key designer, and construction estimation quality are the most important A/E selection criteria.
- Technical experience, design quality, staff quality, bid quality, past performance, design service time, project engagement, project context, key designer, and construction estimation quality have the highest influence on project quality constraints.
- Technical experience, design quality, staff quality, past performance, design service time, project engagement, project context, key designer, and construction estimation quality have the highest influence on project time and cost constraints.
- A reliable and validated Quality Function Deployment (QFD) model was developed to assist owners in selecting an A/E based on qualification criteria and project constraints.

1.1.2 MINOR FINDINGS

For all public projects, the bidding process for A/Es needs to be done through the Ministry of Finance. The Ministry selects the lowest three bids that are within the public

owner's budget. Any A/E can bid for the owner's project, and one of the main issues is selecting an A/E based on price instead of quality. The public project owner can only choose the most qualified bidder out of the three lowest bidders.

One of the private owners evaluates the A/E for the bidding process as follows. The process starts with the initial acceptance of the A/E offices based on a preliminary list of qualification criteria, which will determine the approval or rejection of their bid entry. Once the A/E is approved to enter a bid, the process requires that they submit the bid with two separate packages: a technical package and a financial package. Then, an evaluation process with two steps starts, where the technical package is the first to be opened for evaluation. If the technical package scores an evaluation of at least 70% out 100%, then they are approved technically, and their financial bid is opened. If they don't achieve an evaluation score of at least 70%, then the A/E is disqualified, and their financial package is not permitted to be opened. This process is repeated with all the bidders. After that, all the technically approved bidder's financial packages are opened, and the lowest bidder wins.

1.2 CONCLUSION

Large-size project owners follow systematic approaches for selecting A/E offices to prepare design packages for their projects. However, the used approaches do not yield the desired quality of A/Es, with the majority of the owners not satisfied with their selection. The dissatisfaction stems from project constraints not being achieved, including quality, time, and cost. The newly developed Quality Function Deployment (QFD) model is a

reliable A/E selection system that provides owners with greater chances of selecting the most qualified A/E to prepare design packages for their projects.

1.3 RECOMMENDATIONS

Project owners are advised to use the developed QFD model to select their future A/Es to prepare design packages for their projects. The model is based on qualification criteria and project constraints. The owners are also advised to refrain from awarding design work to A/Es based on project fees, which represents a very small fraction of the project's total cost.

1.4 RECOMMENDATIONS FOR FUTURE STUDY

It is recommended that future studies identify and use additional project constraints other than quality, time, and cost to upgrade the developed QFD model. Future studies should also investigate the applicability of the developed QFD model in selecting A/Es for more than just industrial projects.

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APPENDIX A

QUESTIONNAIRE

**King Fahd University of Petroleum and Minerals
College of Environmental Design
Construction Engineering & Management Department**

**Subject: A/E SELECTION MODEL BASED ON A/E QUALIFICATIONS
AND PROJECT CONSTRAINTS**

Dear Sir,

The study is being performed under the supervision of Professor Ali A. Shash on the evaluation and selection process of architectural engineers (A/E) in Saudi Arabia. The major purposes of the research are to understand the current characteristics of project owners in evaluating, selecting, and procuring A/E services with the owner's level of satisfaction and the A/E selection criteria used by the owners in their evaluation process. Moreover, the survey will evaluate the most important selection criteria to evaluate the performance of the A/E in the selection process. Then, the influence of the A/E selection criteria on the project time, cost, and quality based on the results of the survey will be reviewed. After completing the survey, the research will result in an A/E selection model that could be used by project owners to more accurately select an A/E. If you are interested in applying the model or if you would like to know the results of the research, please share your name and contact information.

The questionnaire consists of five sections as follows:

- a. Section I: General information about the respondents.
- b. Section II: General information about the respondent company.
- c. Section III: Current A/E selection system.
- d. Section IV: Evaluating the importance of A/E selection criteria to measure A/E performance.
- e. Section V: Evaluating influence of A/E selection criteria in project quality, time, and cost.

Please select the most appropriate answers based on your evaluation. Some questions may need you to write in the blank space if the answer is not listed.

I appreciate your assistance in answering the survey questionnaire. Please note that your data will be confidential and used only for educational purposes.

If you need any clarification or are interested in the research results, please do not hesitate to contact me anytime. My contact information is listed below:

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Section I: General information about the respondents

This section contains questions seeking information about the respondent. You are kindly requested to provide the following information in the spaces next to each question.

1. Respondent Information:

Name (Optional)	
Phone (Optional)	
E-mail (Optional)	
Company name: (Optional)	

2. What is your job title?

☐	Managing Director	☐	Manager
☐	Director/VP	☐	Engineer
☐	Senior Manager	☐	Other:

3. What is your level of education?

☐	Ph.D.	☐	Diploma
☐	Master's	☐	High School
☐	Bachelor's	☐	Other:

4. How many years of experience do you have in the construction industry?

☐	<5	☐	≥15 to <20
☐	≥5 to <10	☐	≥20
☐	≥10 to <15	☐	

5. How long have you been with your current employer?

☐	<5	☐	≥ 15 to <20
☐	≥ 5 to <10	☐	≥ 20
☐	≥ 10 to <15	☐	

6. What is your role in the A/E selection process?

☐	Chairman of the selection committee	☐	Other, please specify.....
☐	Member of the selection committee	☐	

Section II: General information about the respondent company.

This section contains questions seeking information about your employer. You are kindly requested to provide the requested information in the spaces next to each question.

1. What is the type of your organization?

☐	Government	☐	Privet
☐	Semi-government	☐	Other:

2. What is the line of your business?

☐	Mining Industry	☐	Fabrication Industry
☐	Electronics Industry	☐	Utilities Services
☐	Petrochemical Industry	☐	Waste treatment or disposal
☐	Oil & Gas Industry	☐	Management Services
☐	Food Manufacturing	☐	Health Care Industry
☐	Manufacturing Industry	☐	Telecommunication Industry
☐	Printing or Media Industry	☐	Hospitality Industry
☐	Basic Manufacturing	☐	Energy Industry
☐	Computer or Electronic Industry	☐	Other:
☐	Automotive Industry		

3. What is the number of employees in your organization?

☐	<50	☐	≥ 250 to <500
☐	≥ 50 to <100	☐	≥ 500 to <2500
☐	≥ 100 to <250	☐	≥ 2500

4. What is the average contract design value (in Saudi Riyals) for construction projects?

☐	<50,000	☐	$\geq 250,000$ to <1,000,000
☐	$\geq 50,000$ to <100,000	☐	$\geq 1,000,000$ to <4,000,000
☐	$\geq 100,000$ to <250,000	☐	$\geq 4,000,000$

5. What is the average project size (in Saudi Riyals) that your organization build annually?

☐	<10,000,000	☐	$\geq 50,000,000$ to <70,000,000
☐	$\geq 10,000,000$ to <30,000,000	☐	$\geq 70,000,000$ to <90,000,000
☐	$\geq 30,000,000$ to <50,000,000	☐	$\geq 90,000,000$

Section III: Current A/E selection system.

This section contains questions seeking information on your employer's current A/E selection system. You are kindly requested to provide the requested information by placing a tic (✓) in the box next to the potential answers.

1. Does your organization prepare a list of potential A/E offices to invite to provide design services?

☐ Yes, if Yes please continue	☐ No, if No please skip to Question number 3.
--	--

2. What are the criteria that are used in selecting an A/E office for the list? (You may select more than one answer)

☐ The A/E design specialization	☐ The A/E past experience with your organization
☐ The type of project that will be designed	☐ Others, please specify..... a. b. c.

3. How does your organization select the A/E from the list?

☐ Sole source selection “contract with a single design firm for a period of time that the firm will perform all engineering tasks under a certain dollar limit.” If selected, please go to question 5.	☐ Based on an established evaluation system. If selected, please continue.
	☐ Other. Please specify:

4. What is the selection system that is used in your organization to procure A/E Services?

Please select from the below options.

	☐ Fixed Budget/Best technical value: The owner provides the budget of the project and proposers are competing in terms of scope and quality, rather than cost.
☐ Quality-based selection: A procurement method used to purchase a service that focuses on the quality of the deliverables.	☐ Weighted criteria: A qualitative proposal contains technical information rated on the basis of points, frequently with the use of a matrix that scores each proposer's response to each of the evaluation criteria and selections based on the highest score value.
☐ Price-based Selection: Based on the evaluation of the proposal cost without any initial consideration for quality.	☐ Best Value Selection: Submitting proposals that are primarily evaluated based on the technical aspects together with the associated cost of the project.
☐ Alternative Delivery Options: Reducing the risk of the procurement method by selecting another type of delivery system, such as design-build or construction management at risk.	☐ Other:

5. The following is a list of potential criteria that are used in the selection of an A/E to design a construction project. You are kindly requested to select the criteria that used in your organization to evaluate A/E by placing a tic (✓) in the box next to the selected criteria.

☐ Technical Experience	☐ Design quality
☐ Past Performance	☐ Design service Time
☐ Customer Satisfaction	☐ Current Workload
☐ Key Designer	☐ Construction estimation quality
☐ Staff Quality	☐ Specialty designing services (Civil, Architectural, mechanical, electrical...etc.)
☐ Design fee	☐ Constructability services
☐ Project Context (Similar project)	☐ A/E Office Location
☐ Financial Standing	☐ Flexibility to suggested design changes
☐ Firm Capacity	☐ Implementation of Saudi Building Code
☐ Reputation	☐ Firm Stability
☐ Number of years in business	☐ References
☐ Percentage of outsourcing work	☐ Bid Quality
☐ Nationality of A/E Ownership	☐ Project Engagement (priority of your project).
☐ Problem Solving	☐ Other: Please specify:

6. Current A/E selection system

The following is a list of potential strength of your current A/E selection system. You are kindly requested to indicate your level of agreement with the listed strengths by placing a tic (✓) in the box next to the selected measurement, where “1” is extremely disagree and “5” is extremely agree.

1	The selected A/E using the current system provides services that meet the project desired <u>quality</u>	Extremely ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Disagree Agree
2	The selected A/E using the current system provides services that lead to completing the project on <u>budget</u>	Extremely ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Disagree Agree
3	The selected A/E using the current system provides services that lead to completing the project on <u>time</u>	Extremely ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Disagree Agree
4	In general, the current A/E selection system is very effective in selecting the proper A/E to design our projects	Extremely ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Disagree Agree
5	In general, our organization is satisfied with the performance of its current A/E selection system in selecting the proper A/E to design our projects	Extremely ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Disagree Agree

6	Other. Please specify: a.	Extremely ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Disagree Agree
7	b.	Extremely ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Disagree Agree
8	c.	Extremely ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Disagree Agree

Section IV: Evaluating the importance of A/E selection criteria to measure A/E performance.

The following are criteria that could be used to measure the performance of an A/E. You are kindly requested to evaluate the degree of importance of each selection criteria that is recommended to be used in evaluating A/E performance. Please select from the below, where 1 is “Extremely not important” to 5 which is “Extremely important”.

1	Technical Experience	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
2	Past Performance	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
3	Customer Satisfaction	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
4	Key Designer	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
5	Staff Quality	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
6	Design fee	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
7	Project Context (Similar project)	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
8	Financial Standing	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
9	Firm Capacity	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
10	Reputation	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
11	Number of years in business	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
12	Percentage of outsourcing work	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
13	Nationality of A/E Ownership	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important

14	Problem Solving	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
15	Design quality	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
16	Design service Time	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
17	Current Workload	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
18	Construction estimation quality	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
19	Specialty designing services (Civil, Architectural, mechanical, electrical...etc.)	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
20	Constructability services	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
21	A/E Office Location	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
22	Flexibility to suggested design changes	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
23	Implementation of Saudi Building Code	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
24	Firm Stability	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
25	References	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
26	Bid Quality	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
27	Project Engagement (priority of your project).	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important
28	Other. Please specify: a.	Not Important	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Extremely Important

b.	Not Important ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Important
.....	
.....	
c.	Not Important ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Extremely Important
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...	

Section V: Evaluating influence of A/E selection criteria in project quality, time, and cost.

The following is a list of criteria that influences achieving the owner's required project objectives, including completing the project on time, within budget, and with the desired required quality. The performance of the consultant in each criterion has a different degree of influence on the desired project objectives. You are kindly requested to evaluate the degree of influence of each selection criteria on each project objective (quality, time, and cost). Please select from each cell below, where 1 has no effect to 5 which is extremely high effect.

	Selection Criteria	Quality	Time	Cost
1	Technical Experience	Choose an item.	Choose an item.	Choose an item.
2	Past Performance	Choose an item.	Choose an item.	Choose an item.
3	Customer Satisfaction	Choose an item.	Choose an item.	Choose an item.
4	Key Designer	Choose an item.	Choose an item.	Choose an item.
5	Staff Quality	Choose an item.	Choose an item.	Choose an item.
6	Design fee	Choose an item.	Choose an item.	Choose an item.
7	Project Context (A/E worked for similar project)	Choose an item.	Choose an item.	Choose an item.
8	Financial Standing	Choose an item.	Choose an item.	Choose an item.
9	Firm Capacity	Choose an item.	Choose an item.	Choose an item.
10	Reputation	Choose an item.	Choose an item.	Choose an item.

11	Number of years in business	Choose an item.	Choose an item.	Choose an item.
12	Percentage of outsourcing work	Choose an item.	Choose an item.	Choose an item.
13	Nationality of A/E Ownership	Choose an item.	Choose an item.	Choose an item.
14	Problem Solving	Choose an item.	Choose an item.	Choose an item.
15	Design quality	Choose an item.	Choose an item.	Choose an item.
16	Design service Time	Choose an item.	Choose an item.	Choose an item.
17	Current Workload	Choose an item.	Choose an item.	Choose an item.
18	Construction estimation quality	Choose an item.	Choose an item.	Choose an item.
19	Specialty designing services (Civil, Architectural, mechanical, electrical...etc.)	Choose an item.	Choose an item.	Choose an item.
20	Constructability services	Choose an item.	Choose an item.	Choose an item.
21	A/E Office Location	Choose an item.	Choose an item.	Choose an item.
22	Flexibility to suggested design changes	Choose an item.	Choose an item.	Choose an item.
23	Implementation of Saudi Building Code	Choose an item.	Choose an item.	Choose an item.
24	Firm Stability	Choose an item.	Choose an item.	Choose an item.
25	References	Choose an item.	Choose an item.	Choose an item.
26	Bid Quality	Choose an item.	Choose an item.	Choose an item.
27	Project Engagement (priority of your project to A/E).	Choose an item.	Choose an item.	Choose an item.
28	Others, please specify a.	Choose an item.	Choose an item.	Choose an item.

	b.	Choose an item.	Choose an item.	Choose an item.
	c.	Choose an item.	Choose an item.	Choose an item.
	d.	Choose an item.	Choose an item.	Choose an item.

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