

A FRAMEWORK FOR IMPLEMENTING MODULAR HOUSING PROJECTS IN SAUDI ARABIA

BY

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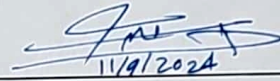


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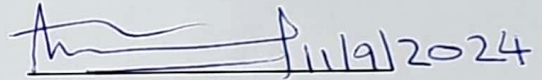


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DEDICATION

This thesis is dedicated to my family, whose unwavering support and encouragement have been the foundation of my journey. To my parents, for their endless love, patience, and sacrifices, which have made all my achievements possible. To my friends, for their understanding and constant encouragement, which made this achievement possible. A special dedication goes to my mentors and advisors for their invaluable guidance and wisdom throughout this project. Without their insights and unwavering belief in my abilities, this thesis would not have been possible. Lastly, I dedicate this work to the dreamers and builders of tomorrow, whose innovative spirits will shape the future of modular housing in Saudi Arabia.

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LIST OF ABBREVIATIONS

CSF : Critical Success Factors

PPMOF : Project organization, engineering, procurement, planning,
monitoring, coordination.

OSP : Off-site production

CII : Construction Industry Institute

IMC : Intermodular connection

ABSTRACT

Full Name : Tarig Arif Awad Abdelhalim

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The growing demand for rapid and sustainable housing solutions in Saudi Arabia has highlighted the potential of modular housing to address such needs effectively. Despite its potential to revolutionize the housing sector, there is limited knowledge on how to effectively implement modular construction in specific contexts, such as Saudi Arabia. This gap necessitates a comprehensive investigation into the critical success factors (CSFs) that drive project success. Thus, this research aims to develop a stage-gate success factors model for implementation of modular housing projects in Saudi Arabia. A comprehensive literature review and feedback of subject-matter experts were employed to explore the CSFs of housing projects in Saudi Arabia. Data were collected from various stakeholders in the construction industry, including general contractors, subcontractors, consultants, and architects. The study used mixed methods, applying quantitative analysis for the broad survey data and qualitative analysis for the in-depth case studies.

The findings revealed that modular housing significantly enhances project delivery times, cost efficiency, and sustainability. CSFs identified include effective project management, integration of advanced manufacturing techniques, and stringent quality control. The CSFs were characterized and distributed into five distinct phases of project development: Planning, Design, Manufacture, Transportation, and Assembly. This classification was

supported by interviews with 10 specialists in the modular housing industry. The specialists' contributions were instrumental in shaping the stage-gate success factors model, providing a clear pathway for project execution from conception to assembly. The framework was validated and using real modular housing projects. The research indicates a lack of nuanced understanding of how external variables can significantly impact the efficacy of established frameworks and highlights the need for adaptable approaches that can accommodate unique project constraints. The proposed stage-gate success factors model and identified CSFs provide a structured approach to implementing modular housing projects, supporting Saudi Arabia's Vision 2030 for sustainable urban development.

ملخص الرسالة

الاسم الكامل : طارق عارف عوض عبدالحليم

عنوان الرسالة : إطار عمل لتنفيذ مشاريع الإسكان المعياري في المملكة العربية السعودية

التخصص : إدارة وهندسة التشييد

تاريخ الدرجة العلمية : 2024/5/29

لقد أبرز الطلب المتزايد على حلول الإسكان السريعة والمستدامة في المملكة العربية السعودية الإمكانات التي يوفرها الإسكان المعياري لمعالجة هذه الاحتياجات بفعالية. تهدف هذه الدراسة إلى تطوير إطار عمل متدرج لتنفيذ مشاريع الإسكان المعياري في المملكة العربية السعودية. تم استخدام مراجعة شاملة للأدبيات مقترنة بمنهجيات بحثية تجريبية، بما في ذلك الاستبيانات وحالات الدراسة التي اشتملت على أربعة مشاريع للإسكان المعياري في المملكة العربية السعودية، لاستكشاف العوامل الحاسمة للنجاح (CSFs) لمشاريع الإسكان في المملكة العربية السعودية. تم جمع البيانات من مختلف أصحاب المصلحة في صناعة البناء، بما في ذلك المقاولين العامين والمقاولين من الباطن والمستشارين والمهندسين المعماريين. استخدمت الدراسة طرقاً مختلطة، تطبيق التحليل الكمي لبيانات الاستطلاع الواسع والتحليل النوعي لدراسات الحالة المعمقة. كشفت النتائج أن البناء المعياري يعزز بشكل كبير من أوقات تسليم المشاريع، كفاءة التكلفة، والاستدامة. تم تحديد العوامل الحاسمة للنجاح وتشمل إدارة المشاريع الفعالة، وتكامل تقنيات التصنيع المتقدمة، والرقابة الصارمة على الجودة. ومع ذلك، تم توصيف هذه العوامل بدقة وتوزيعها إلى خمس مراحل متميزة من تطوير المشروع: التخطيط، التصميم، التصنيع، النقل، والتجميع. وقد دعمت هذه الاستقصاءات المفصلة، المعززة بمقابلات مع 10 من المتخصصين في صناعة الإسكان المعياري، فهم كل دور للعوامل الحاسمة للنجاح وأكدت أهميتها في جميع مراحل المشروع. كانت مساهمات المتخصصين حاسمة في تشكيل نموذج المراحل المتعددة، مما وفر

مسارًا واضحًا لتنفيذ المشروع من الفكرة إلى التجميع. لم يتم التحقق من هذا الإطار فقط بشكل كمي ولكن أيضًا تم تعزيزه برؤى نوعية تبرز الترابطات المتبادلة والتأثير الجماعي لهذه العوامل على نجاح المشروع، وتشير الدراسة إلى نقص في الفهم المتقن لكيفية تأثير المتغيرات الخارجية بشكل كبير على فعالية الأطر المؤسسة وتسلط الضوء على الحاجة إلى مناهج مرنة يمكنها استيعاب القيود الفريدة للمشروع. يوفر النموذج المرحلي المقترح والعوامل الحاسمة للنجاح المحددة نهجًا منظمًا لتنفيذ مشاريع الإسكان المعياري، داعيًا رؤية المملكة العربية السعودية 2030 للتطوير الحضري المستدام.

CHAPTER 1

1. INTRODUCTION

This chapter serves as a concise introduction to the thesis, laying the groundwork by detailing the research's background and pinpointing the critical research problem it aims to address. It articulates the necessity to fill the identified research gap and delineates the specific research questions that require thorough investigation. The chapter concludes by offering a structured overview of the thesis's organization, guiding the reader through the upcoming sections and their content.

1.1 BACKGROUND

Over the past six decades, the global construction industry has faced profound performance challenges that require immediate attention and proactive solutions. Overcoming issues related to cost escalation, project delays, quality control, sustainability, skilled labor shortages, and technological integration is vital for the industry's growth, competitiveness, and long-term viability (Abdel-Wahab et al., 2011). Traditional construction methods encounter multiple obstacles in adapting to the changing demands of the construction industry. As a call for sustainable, efficient, and cost-effective building solutions grows, the limitations of conventional construction practices become increasingly evident. The sequential and on-site nature of these processes the construction method frequently result in extended project durations, project delays, and difficulties in coordinating multiple

subcontractors. Moreover, the reliance on manual labor introduces the risk of human error, leading to inconsistencies in quality and potential safety hazards (Haron et al., 2018).

Conventional construction is frequently linked to substantial material waste, giving rise to environmental issues and heightened expenses. An additional obstacle is the restricted flexibility and adaptability inherent in traditional construction methods. The design and construction stages are typically distinct, making it difficult to integrate alterations or adjustments during the construction process without incurring substantial time and cost consequences (Dlamini et al., 2021). Traditional construction frequently encounters sustainability-related obstacles. The extensive dependence on conventional building materials and practices can result in significant environmental repercussions, including carbon emissions, depletion of resources, and generation of waste. Given these challenges, alternative construction approaches like Modular housing have emerged as encouraging solutions. Modular housing tackles numerous limitations associated with conventional methods through the utilization of off-site fabrication, streamlined processes, and enhanced resource management (Agyekum et al., 2013).

The demographic and housing landscape in Saudi Arabia is undergoing significant changes, driven by rapid population growth and an increasing demand for affordable housing. The population surged from 7 million in 1974 to 31 million in 2020, with a notable majority (67%) under 34 years old, indicating a youthful demographic profile (Mulliner & Algrnas, 2018). Projections suggest a continuation of this trend, with an expected population of 37 million by 2025, growing at an annual rate of 1.9% (Santoso et al., 2017). This demographic shift is contributing to a pronounced housing demand, necessitating the

construction of approximately 300,000 housing units annually to meet the needs of a young and expanding populace.

The Ministry of Investment (MISA) forecasts that by 2030, the demand for new housing units will reach 1.5 million, doubling the current market supply and highlighting the inadequacies of traditional construction methods to satisfy this growing need. Presently, traditional construction practices yield around 150,000 units annually but are criticized for inefficiencies, including low productivity, poor quality, high energy and material consumption, workplace accidents, and environmental degradation (Alshuwaikhat & Mohammed, 2017).

In response, the Saudi government and the Ministry of Housing have embarked on strategic initiatives aimed at transforming the construction industry. The Building Technology Stimulus Program, a pivotal government initiative, promotes the adoption of advanced construction techniques to enhance efficiency, quality, and sustainability. This program prioritizes cost reduction, time savings, quality and productivity improvement, diversity, and local content, including job creation for Saudis. It has successfully endorsed various structural and Modular housing solutions that align with these goals. Additionally, the program facilitates financial support for Modular Housing providers, offering up to 75% of initial investment costs through the Saudi Industrial Fund (SIF), covering land acquisition, factory setup, training, and initial operational capital for six months (Shash et al., 2020).

Industrialization in construction has been proposed as a potential solution to improve construction performance. This involves the adoption of production technologies and

standardized product designs that can be manufactured off-site. Through exploration of off-site methods, Modular housing has emerged as a promising approach due to its notable advantages in terms of sustainability and productivity when compared to traditional construction methods. Modular housing, which involves constructing buildings through prefabricated modules, has transformed the construction sector by offering various benefits such as decreased construction duration, enhanced quality control, better cost estimation, and heightened sustainability. Modular housing has emerged as a pioneering strategy for fulfilling the constantly changing requirements of the housing sector (Pan et al., 2012).

The controlled factory setting enables simultaneous work on multiple modules, eliminating delays caused by weather conditions and optimizing overall productivity. Consequently, modular housing enables expedited project delivery, making it an excellent choice for pressing housing demands, post-disaster reconstruction, and time-critical commercial projects (Jönköping, 2018). The streamlined and standardized production processes employed in Modular housing contribute to enhanced cost efficiencies (Abdelmageed, Abdelkhalek, et al., 2020). The controlled manufacturing environment in factories reduces material waste, optimizes resource utilization, and decreases labor needs, resulting in cost savings for builders and homeowners alike. Furthermore, the capability to accurately predict project costs and minimize budget deviations makes modular housing an appealing choice for individuals seeking affordable and predictable construction outcomes (Sabharwal et al., 2009). Modular housing also provides outstanding quality and craftsmanship. The factory environment facilitates rigorous quality control measures at every stage of the construction process. Utilizing skilled labor and advanced technologies ensures precision and consistency in module fabrication, resulting in exceptional structural

integrity and overall construction quality. Moreover, the incorporation of advanced design and engineering software empowers architects and builders to create innovative and personalized modular designs that meet the highest benchmarks of aesthetics and functionality (Velarde et al., 2009). With the increasing demand for efficient, affordable, and environmentally conscious housing solutions, modular housing stands as a transformative influence in shaping the trajectory of the construction industry (Bachelor, 2012)

Modular housing encounters different barriers. For instance, Modular housing can encounter constraints in terms of design customization when compared to conventional construction technique (kazem zadeh et al., 2020) . The transportation of modular units to the construction site can present difficulties, particularly for projects situated in remote or hard-to-reach locations (Hořínková, 2021). Certain regions may have unique regulations or limitations that hinder the acceptance and execution of modular housing projects.(Choi et al., 2017). Modular housing might encounter doubt or reluctance from prospective buyers, developers, or industry experts who are unfamiliar with its advantages and capabilities (Loizou et al., 2021a). Developing Modular housing capabilities and obtaining the requisite expertise and equipment can entail substantial initial expenses and necessitate specialized knowledge and skills (Hořínková, 2021).

The Stage Gate Model is a well-organized system utilized to oversee innovation projects and the process of developing products. It divides the development process into clear-cut stages, and at the conclusion of each stage, there are decision points or gates. At these gates, a group of decision-makers assesses the project's advancement, feasibility, and alignment with strategic goals, and based on their evaluation, they decide whether to proceed to the

next stage, make modifications to the project, or terminate it (R. G. Cooper, 1990). Within the Scope of modular housing, the Stage Gate Success Model tackles crucial elements for achieving success, including optimizing modular design, enhancing module manufacturing capabilities, streamlining transportation logistics, improving on-site assembly efficiency, ensuring quality assurance, and prioritizing customer satisfaction. By incorporating these factors into the framework, organizations engaged in modular housing can systematically confront the unique challenges of this industry, ultimately increasing the probability of achieving favorable project outcomes (Sethi et al., 2008). The Stage Gate Model concept places a strong emphasis on fostering collaboration and active participation among essential parties involved, such as architects, engineers, contractors, module manufacturers, suppliers, and end-users. This model advocates for cross-functional engagement, promoting efficient communication and coordination during the entire project duration. By incorporating diverse viewpoints and specialized knowledge, the model facilitates well-informed decision-making, minimizes risks, and optimizes the allocation of resources within modular housing projects (R. Cooper, 2015).

The research's focus is on a detailed assessment of CSFs pertinent to modular housing within Saudi Arabia, strategically categorized into five key phases of a stage-gate success factors model. This structure allows for a systematic exploration of each phase's distinct CSFs, enhancing the understanding of modular housing's efficacy in meeting the nation's housing demands. By involving industry experts, the research ensures a comprehensive perspective is incorporated, culminating in a tailored framework that aligns with Saudi Arabia's unique housing sector requirements.

1.2 STATEMENT OF THE PROBLEM

Without a clear categorization of CSFs into Stage-Gate, it becomes challenging to apply focused oversight and control at each phase of the project. This can lead to oversight gaps where some critical factors might not receive the attention they require at crucial stages, thereby increasing project risk. Categorized CSFs facilitate quicker responses to changing project dynamics. A non-categorized approach might slow down response times and reduce the project's adaptability to new challenges or information (Moshood et al., 2020). The residential sector in Saudi Arabia faces some obstacles in implementing modular housing projects, primarily due to the limited number of companies that have expertise in modular housing. As a result, project stakeholders may encounter challenges in finding contractors who can offer modular housing services. Furthermore, there is a shortage of experience in this area (Aburas, 2011). Modular housing presents additional logistical challenges compared to conventional methods, large modules need to be transported to the construction site using trucks, which can be risky. This poses a risk of expensive accidents occurring during transportation, and construction firms may have to pay higher insurance premiums (The Report Saudi Arabia 2020 - Digital Version, 2020).

One of the obstacles pertains to the design and aesthetics of modular buildings. The use of prefabricated rooms in modular housing significantly restricts the design options available. The rooms must be compact and ergonomically designed to ensure safe transportation and assembly. Although modular housing may appear simple at first glance, it requires extensive upfront planning. Modular architecture requires careful consideration of how all modules can fit together in a safe and comfortable manner. This complexity may deter

some construction companies from adopting modular housing techniques (Hořínková, 2021).

This research aims to examine how the integration of the Stage Gate Success Model with modular housing can effectively address these challenges, simplify the construction process, improve project efficiency, and guarantee the prompt provision of top-notch housing units. By combining the Stage Gate Success Model with modular housing, the unique challenges faced by the housing sector in Saudi Arabia are effectively tackled. A key challenge lies in the requirement for swift construction to cater to the growing population. Modular housing, with its off-site fabrication and concurrent construction processes, considerably shortens construction timelines compared to conventional approaches (Johnsson et al., 2009). The combination of the Stage Gate Success Model with modular housing provides a holistic answer to the housing problem in Saudi Arabia. This integration optimizes the construction process, improves project efficiency, and guarantees the provision of top-quality housing units, meeting the urgent demand for affordable, sustainable, and timely housing solutions. By incorporating innovative construction practices and structured project management, Saudi Arabia can successfully overcome its housing challenges, enhancing the living conditions and overall quality of life for its residents.

1.3 RESEARCH OBJECTIVES

The objectives of this research are to:

1. Identify and prioritize the critical success factors for implementing modular housing projects in Saudi Arabia.

2. Develop a stage-gate success factors model for implementing modular housing projects.
3. Validate the stage-gate success factors model using experts' feedback and actual case studies of modular housing projects.

1.4 RESEARCH SIGNIFICANCE

Saudi Arabia is investigating the use of modular housing as a solution to the country's rising demand for housing, particularly among its expanding and youthful population. The Saudi government has acknowledged the requirement for affordable, sustainable, and top-notch housing to aid in the achievement of its long-term economic and social development objectives (Alshebli, 2018). Modular housing is playing a vital role in meeting the Ministry of Housing's demand for housing units in Saudi Arabia. The use of modular housing techniques promotes sustainable construction practices by reducing material waste, energy consumption, and on-site pollution, which is consistent with the goals of Saudi Arabia's Vision 2030 to support sustainable development and environmental preservation (Alshuwaikhat et al., 2017). A key factor for the successful implementation of modular housing lies in ensuring that all project members have a comprehensive understanding of the modular housing method and the intricacies of its system implementation. This includes architects, engineers, contractors, suppliers, and other stakeholders involved in the construction process.

Understanding the modular housing method entails familiarity with the unique aspects of off-site fabrication, transportation, and on-site assembly. Project members need to grasp the fundamental principles of modular housing, including the modular design process, the fabrication techniques employed in the factory, and the specific requirements for module transportation and installation. By acquiring this knowledge, project members can effectively collaborate, communicate, and make informed decisions throughout the construction journey (Santoso et al., 2017). The implementation of various projects across sectors such as education, healthcare, commercial, and industrial is bringing Saudi Arabia's ambitious plans to fruition. This has resulted in an increased demand for modular housing techniques in the country. For example, with the support of the Ministry of Housing, the modular housing project is expected to aid Saudi Arabia's homeownership strategy, which aims to have 70% of its residents' owning homes by 2030 (Aburas, 2011).

1.5 RESEARCH LIMITATION

The findings and conclusions of this research may have limited generalizability beyond the context of Saudi Arabia. The critical success factors identified, and the proposed model may be influenced by the specific socio-cultural, economic, and regulatory conditions of the country, and may not be directly applicable to other regions or countries. The research may face limitations in terms of long-term evaluation of the proposed critical success factor model. Modular housing projects typically require a longer time to assess their long-term performance, including aspects such as durability, maintenance, and user satisfaction. Conducting such evaluations may extend beyond the scope and timeline of this research.

The research may be limited in terms of the perspectives captured from various stakeholders involved in the implementation of modular housing projects in Saudi Arabia. While efforts will be made to engage relevant stakeholders, such as policymakers, developers, and contractors, constraints such as access, willingness to participate, and representation may impact the comprehensiveness of the stakeholder perspectives included in the research.

1.6 THESIS STRUCTURE

This opening chapter sets the stage for the entire research. It delineates the main themes, presents the research background, and precisely defines the research problem the research seeks to address. By highlighting the existing gap in the literature, it establishes the research's research questions, objectives, and aims. Additionally, this chapter outlines the contextual and geographic scope of the research, provides a summary of the research methodology employed, and underscores the significance and importance of the conducted research. The second chapter lays the theoretical and conceptual groundwork for the research. It begins with clear definitions of key terms and concepts critical to understanding modular housing in Saudi Arabia. Following this, the chapter offers systematic reviews that culminate in a comprehensive checklist of CSFs for modular housing projects within the region. This detailed exploration aids in framing the research within the broader academic and practical discourse on modular housing. In the methodology chapter, the research's research process and methodologies are thoroughly detailed. It explains the research paradigm adopted, outlines the research design, and describes the methods used for data collection and the techniques applied for data analysis. This chapter is vital as it

provides a transparent view of the research methods employed and the analytical approaches taken, ensuring the research's reliability and validity.

This chapter presents the findings from the data collected through both quantitative and qualitative research methods. It meticulously analyzes the responses from industry professionals and experts, detailing the identification, categorization, and ranking of the CSFs for modular housing in Saudi Arabia. The results are presented in a structured manner, with data visualizations where necessary, to highlight the key outcomes of the research and provide insights into the empirical evidence gathered. The concluding chapter synthesizes the findings from the research, linking back to the research questions, objectives, and the theoretical framework established in the earlier chapters. It discusses the implications of the findings for practitioners, policymakers, and future research in the field of modular housing in Saudi Arabia. Additionally, this chapter reflects on the limitations of the research and proposes areas for further research. It culminates with a summary of the study's contributions to the field and its potential impact on the advancement of modular housing projects within the unique context of Saudi Arabia.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter conducts an extensive literature review on modular housing, beginning with an explanation of modularization, prefabrication, preassembly, and off-site fabrication. It clarifies the terminology used across different sectors within the construction industry, highlighting the diversity of applications and the need for standardized definitions. Following this foundational overview, the chapter delves into the concept of CSFs that significantly influence the success of modular housing projects. It outlines the key CSFs identified in the literature, such as planning and design, effective project management, skilled labor, and efficient logistics, underscoring their importance for the successful implementation of Modular housing. The review then identifies a research gap in the detailed understanding of these CSFs within the modular housing process, particularly in the Saudi Arabian context. Addressing this gap, the chapter proposes the use of a stage gate model to systematically explore and rank the CSFs relevant to each stage of modular housing - from planning through to on-site assembly. The aim is to offer a nuanced analysis of how these factors contribute to the efficacy and efficiency of modular housing projects, providing a structured approach to enhancing project outcomes. This chapter sets the stage for the research by establishing a clear direction for investigating the CSFs of modular

housing in Saudi Arabia. It highlights the significance of the findings for the construction industry, promising to offer valuable insights into optimizing the Modular housing process.

2.2 MODULAR HOUSING

Modularization is the act of creating a fully functional system away from the designated work location and then moving it to the site. The modules used in this procedure are typically sizable and may require disassembly into smaller components for easier transportation (Haas et al., 2000). A "module" is a substantial section of a factory or building that is manufactured through different assembly methods at a remote site and may encompass components from multiple systems. It is usually the largest and most important movable part or element of a facility (Tatum et al., 1986). Prefabrication is an exclusive manufacturing technique that involves combining different materials to produce a component part, which is then installed as a final product. This process is typically conducted at a specialized facility dedicated to such operations (Tatum et al., 1986). Preassembly is a technique where pre-manufactured parts or equipment are assembled in a separate location, allowing them to be later installed as a fully integrated unit. This approach is commonly employed when constructing a particular system (Tatum et al., 1986).

Off-site fabrication refers to the practice of assembling or manufacturing components in a location other than the actual installation site. This can either be done in a separate off-site facility or at the installation site itself, but not at the final position where the components will be placed (CII, 2002). Several methods have been developed to enhance the manufacturing and installation processes by transferring various fabrication and

installation tasks from the plant site to a safer and more efficient environment. These methods include prefabrication, preassembly, modularization, and offsite fabrication (PPMOF). They all aim to optimize operations by conducting crucial tasks in controlled environments away from the actual installation site, resulting in improved safety and efficiency.(CII, 2002).

In the industry, (PPMOF) is occasionally referred to as prework (Song et al., 2005). As per the literature, it has been discovered that the construction industry has different definitions for the mentioned terms and even different opinions due to differences between the building and industrial sectors regarding the adoption of the module (CII, 2002; Tatum et al., 1986). The modular housing industry frequently uses the term "off-site production" (OSP) (A. G. F. Gibb, 1999). It is important for readers to recognize the distinctions between these industries and utilize the definition that is suitable for their specific sector. Modular housing provides improved control over production quality and has the capability to increase construction efficiency, safety, and sustainability (Blismas et al., 2009) . Numerous research studies have explored various classifications of modular housing based on the extent of on-site and off-site activities as summarized in Table 1. Subsequently, the author presents a tabulated form in Table 1 to outline the different types of modular housing, accompanied by their respective definitions and examples. Analyzing these classifications will facilitate the creation of modular typologies, thereby examining the existing practices within the industry.

Table 2.2 Modular housing Classification

Source	Types	Term/Definition	Examples
(A. Gibb, 2001a; A. Gibb et al., 2010)	Manufacturing of Components and Sub-Assembly of Non-Volumetric Components in Advance	Small-scale Sub-Assembly of Construction Project Off-Site Production Items Pre-Fabricated and Assembled in the Factory before Final Placement. Comprises a Significant Structural Element of the Project but Does Not Generate Usable Space.	Door Hardware, Lighting Fixtures, and Windows Wall Panels, Plumbing Assemblies, Structural Elements, and Cladding Panels
	Pre-Assembly of Volumetric Components	Creates a self-contained module within a separate structural framework.	Equipment Enclosure, Modular Bathroom Units, and Vertical Transport Shaft
	Prefabricated/ Fully Assembled Structure	Comparable to volumetric modules, but encompasses the entire project with functional space. External finishes are applied at the construction site.	Stores for selling goods, workspaces, correctional facilities, and residential buildings with multiple floors.

2.3 CRITICAL SUCCESS FACTORS

The CSFs refer to essential elements that can significantly impact the performance of a strategy in a positive way (Raravi, 2013). (Rockart, 1979) introduced this concept, emphasizing the need for organizations to have control over their CSFs to achieve success. (Freund, 1988) defines CSFs as "the things that a company must do to be successful,"

referring to the factors within an organization that contribute to its competitiveness. CSFs should not be misconstrued as competitive advantage, as the latter can only be attained by a select few players within a specific market. Instead, CSFs can be possessed by all organizations in any market and are necessary for survival. The preceding paragraph explains that CSFs refer to the essential elements within an organization that are necessary for competing and surviving. One of these elements is customers, as they have a significant influence on what an organization should prioritize to appeal to them. This is supported by research conducted by (Keats, 1988; Selim, 2007).

Implementing industrial modularization successfully involves considering several factors. (Tatum et al., 1986) mentioned that using PPMOF can lead to changes in project organization, engineering, procurement, planning, monitoring, coordination, communication, and transportation, which can add complexity to the project. In addition, it should be noted that design change flexibility is reduced when implementing modular housing. In the building modular sector, (A. Gibb et al., 2010b) identified several success factors from the owner's perspective for preassembly implementation. These success factors include an early design freeze, reasonable lead times, adequate time for preside prototyping, early vendor involvement, and the owner's understanding of the benefits and limitations of modular housing. Based on the literature review, there are several success factors that have been documented, including early consideration, alignment on drivers, the adoption of new technology, design freeze, standardization, the development of fabrication infrastructure, and improvement in logistics (Jung et al., 2021).

It is ideal to include a modularization strategy at the beginning of a project, as recommended by. (Peltokorpi et al., 2017; Song et al., 2005) emphasized the importance

of systematic analysis and early decision-making based on project-specific factors for the successful implementation of PPMOF.

Increased utilization of modularization can be enabled through construction's unrestricted involvement in the design phase throughout all project stages (Akagi et al., 2002). When all stakeholders agree and are informed about the potential benefits, the chances of successful modularization implementation are increased. The broader adoption of modularization can also be supported by technological advancements. According to (Salman et al., 2012), progress in design and information technologies plays a crucial role in making modularization more feasible. For instance, the growing use and development of 3D technology and building information modeling (BIM) are among the advancements that have been effective. (Neelamkavil, 2009) anticipated that automation will be beneficial for the prefabricated and modular housing industry. The author explained that automation technologies encompass various areas, such as automated design, supply network and materials management, robotics automation in prefabricated factories, automated construction site, virtual reality and simulation, and scheduling automation and sensor-based control. The use of standard/subsequent design has been suggested by the shipbuilding and automotive industries. The automotive industry largely implements the concept of design for manufacturing (Karl Ulrich and David Sartorius and Scott Pearson and Mark Jakiela, 1993; Venkatachalam et al., 1993). Construction Industry Institute has suggested using block design and standard design for modern shipbuilding to achieve cost benefits through economies of scale (CII, 2002). (A. Gibb et al., 2010) discussed the implications of standardization from the client's point of view in the building industry.

The critical success factors are divided into main five stages of modular housing, including planning, design, manufacturing, transportation, and on-site assembly. Efficient management and supervision of construction activities are crucial for achieving outstanding outcomes (Rodrigues et al., 2014; Thomas et al., 2008). To achieve a successful project, it is necessary to meet several objectives such as timely delivery, staying within budget, and meeting quality standards. Other goals such as safety, sustainability, and reliability were also crucial.

2.4 PLANNING STAGE

Modular housing involves the prefabrication of building sections or modules in a controlled factory setting, which are then transported and assembled on-site. The planning stage in modular housing is critical as it sets the groundwork for the entire project, encompassing aspects such as site evaluation, design, compliance with regulations, and logistics planning. Effective planning is instrumental in aligning the project objectives with operational execution and ensuring that the subsequent stages proceed smoothly. Regarding CSF in the planning stage, Research has highlighted the significance of selecting an optimal site that supports the logistical needs of transporting and assembling modular units (Hsu et al., 2018). Planning must include a thorough regulatory review to streamline the approval process and reduce project delays (Khoiry et al., 2018). Early integration of design and engineering teams helps in creating designs that are optimized for Modular housing, reducing the need for later adjustments (Hyun et al., 2020). This integration supports the standardization of modules, facilitating better quality control and efficiency in production (Liao et al., 2010). The planning stage in modular housing is foundational because it

directly influences all subsequent stages of the project. Studies have shown that meticulous planning can significantly reduce risks associated with Modular housing, such as project delays, cost overruns, and quality issues (Akinradewo et al., 2021). Additionally, robust planning enhances project predictability and stakeholder confidence, contributing to the overall success of the project.

2.5 DESIGN STAGE

Modular product design is a product design approach that involves assembling a product from a collection of smaller modules that can be independently designed but work together as a complete unit (Baldwin et al., 2000). Modular product design aims to decrease the reliance between the different components of a product by comprehensively defining the functions and interfaces of each module (Ulrich et al., 2016). Modular product design simplifies the complexity of a product system by breaking it down into sets of independent modules, as stated by (Baldwin et al., 2000). Therefore, developing a complex product is akin to designing and constructing a set of less complicated modules that enable design flexibility and testing.

2.6 MANUFACTURE STAGE

Typically, there are three main stages involved in the factory before modules are transported: manufacturing of subassemblies, module assembly, and module completion (Farnsworth, 2015). Steel-framed modular units are generally assembled using either static or linear production systems (Jeonghoon Lee et al., 2016). A static production system involves a team of specialized workers who move from one workstation to another where modules are waiting to be fitted out, while in a linear production system, modules are

transported along a production line on rails and pass through a series of substations where different specialists work on them (Jeonghoon Lee et al., 2016). The static production system is more efficient in producing customized modules, while the linear production system is better suited for producing standardized modules in large quantities, in terms of production efficiency. Designing appropriate material and information flow between assembly operations and balancing workload distribution across workstations are essential for optimizing production productivity and efficiency. However, it is a challenging task for module manufacturers (Jeonghoon Lee et al., 2016; Mullens, 2011). (Sabharwal et al., 2009) found that improving the manufacturing process of subassemblies can lead to an overall improvement in production performance. Restructuring a series of tasks in wall and floor fabrication into a parallel workflow can result in increased output rates and reduced material handling costs. To modularize assembly activities, the Dependency Structure Matrix (DSM) method is used to analyze the relationship between information flow and tasks, which can help reduce interdependencies between operations and streamline the production process (Joosung Lee et al., 2017; Mullens, 2011).

2.7TRANSPORTATION STAGE

The primary and most crucial factor in modular housing is to guarantee the modules' transportation to the desired location. If larger cranes become more readily available, modular housing may become more widely accepted. Integrated service companies can assist inexperienced contractors and owners in meeting their cost and schedule objectives by providing comprehensive planning, logistics, heavy lifting, and transportation services (Youdale, 2009). The process of on-site assembly of modular buildings provides builders with the flexibility to customize the building design and adjust the modules during the

assembly process to suit specific site conditions or client requirements. This approach also enables better integration of the modular building with the surrounding environment, including existing buildings, landscaping, and infrastructure. The outcome is a more attractive and functional structure that meets the needs of the client.

2.8 ASSEMBLY STAGE

(Sharafi et al., 2018) proposed an interlocking system that simplifies the assembly process by automatically enabling connection with lower force and simpler motions, as stated in the literature. (Lacey et al., 2021) proposed simplified structural models for interlocking intermodular connection (IMC), allowing them to predict interlocking connection behavior. (Chen et al., 2017) proposed new beam-to-beam tenant and bolt connections, which facilitate the horizontal connection of modules with a tenant acting as a horizontal geometrical constraint as well as vertically positioning the modules. However, on-site installation of bolts is required to prevent disconnection in the case of a tensile load (Annan et al., 2009). Table 2 outlines the critical success factors identified from the literature, showcasing a variety of sources and the specific factors they highlight as crucial for the success of modular housing projects. This table serves as a foundational reference for understanding how these factors contribute to various stages of the modular housing process.

Table 2.8 Critical success factors of modular housing

NO.	Critical Success Factor	Sources
1	Adequate planning and design	(Carriker et al., 2014; Jung et al., 2021a; Lau, 2011; L. Li, Li, Guangdong, et al., 2018; Wuni et al., 2019)

2	Effective project management	(Carriker et al., 2014; Choi et al., n.d.; L. Li, Li, Guangdong, et al., 2018; O'Connor et al., 2014a; Wuni et al., 2019)
3	Skilled and experienced labor force	(Carriker et al., 2014; Gosling et al., 2016; Wuni et al., 2019)
4	Proper factory layout and equipment	(Lau, 2011; O'Connor et al., 2014; Selim, 2007)
5	Efficient transportation and logistics	(Carriker et al., 2014; Gosling et al., 2016; Wuni et al., 2019)
6	High-quality materials and components	(Hořínková, 2021; Lau, 2011; O'Connor et al., 2014; Wuni et al., 2019)
7	Compliance with building codes and regulations	(Gosling et al., 2016; C. Haas et al., n.d.; Wuni et al., 2019)
8	Effective communication between stakeholders	(Ali et al., 2023; Jung et al., 2021a; L. Li, Li, Guangdong, et al., 2018; O'Connor et al., 2014a; Selim, 2007; Wuni et al., 2019)
9	Adequate funding and financial planning	(Abdulmajeed et al., 2022; Blismas et al., 2009; Lau, 2011; L. Li, Li, Guangdong, et al., 2018; O'Connor et al., 2014; Selim, 2007)
10	Adequate insurance coverage	(Shash et al., 2020)
11	Proper site preparation and foundation work	(Shash et al., 2020)
12	Effective quality control measures	(A. Gibb, 2001a; Jung et al., 2021; Lau, 2011; L. Li, Li, Guangdong, et al., 2018; O'Connor et al., 2014; Selim, 2007)
13	Use of sustainable and environmentally friendly materials	(Al Surf et al., 2013; Lau, 2011; Navarro Rubio et al., 2018)
14	Integration with existing infrastructure and utilities	(Elshennawy et al., 2002; C. Haas et al., n.d.; Lau, 2011; L. Li, Li, Wu, et al., 2018a; Yahaya Wuni et al., 2020.)

- 15 Compliance with safety standards and regulations (Gunawardena et al., 2022; Jung et al., 2021b; X. Li et al., 2017; Wuni et al., 2019)
- 16 Effective marketing and branding (Lau, 2011)
- 17 Adaptability to changing market demands (Lau, 2011)
- 18 Availability of reliable suppliers and subcontractors (Shash et al., 2020)
- 19 Use of innovative technologies and processes (Lau, 2011)
- 20 Efficient use of space and resources (Lau, 2011; Wuni et al., 2019)
- 21 Effective waste management practices (Fan, 2010; Loizou et al., 2021b)
- 22 Effective risk management strategies (Wuni et al., 2019)
- 23 Flexibility in design and customization options (Lau, 2011)
- 24 Compliance with health and hygiene standards (Loizou et al., 2021)
- 25 Availability of warranty and after-sales services (Jung et al., 2021; Lau, 2011)
- 26 Efficient energy usage and conservation measures (Gosling et al., 2016; Lau, 2011)
- 27 Effective cost management and budgeting (Ali et al., 2023; Blismas et al., 2009; Lau, 2011; L. Li, Li, Guangdong, et al., 2018; O'Connor et al., 2014a; Selim, 2007; Wuni et al., 2019)
- 28 Proper training and development of employees (Carriker et al., 2014)
- 29 Effective use of data analytics and performance metrics (Gosling et al., 2016)
- 30 Ongoing research and development to stay competitive (Wuni et al., 2019)

- | | | |
|----|---|---|
| 31 | Effective supply chain management | (Blismas et al., 2009; Wuni et al., 2019) |
| 32 | Timely delivery of modules to site | (Blismas et al., 2009; Jung et al., 2021a; Lau, 2011; L. Li, Li, Wu, et al., 2018b; O'Connor et al., 2014a; Selim, 2007; Wuni et al., 2019) |
| 33 | Efficient assembly and installation of modules on site | (A. Gibb et al., 2010a; Lau, 2011; Sparkman et al., 1999) |
| 34 | Use of standardized building components and systems | (Lau, 2011; Wuni et al., 2019) |
| 35 | Effective design for transportation and shipping | (Wuni et al., 2019) |
| 36 | Proper handling and storage of modules during transportation and on site | (Blismas et al., 2009; Lau, 2011) |
| 37 | Effective insulation and weatherproofing measures | (A. Gibb et al., 2010a; C. T. Haas et al., 2002; Sparkman et al., 1999) |
| 38 | Compliance with fire safety regulations | (Velarde et al., 2009; Wuni et al., 2019) |
| 39 | Effective soundproofing and noise reduction measures | (Blismas et al., 2009; Lau, 2011) |
| 40 | Use of advanced building techniques, such as modular framing and panelization | (Lau, 2011) |
| 41 | Adequate contingency planning and emergency response measures | (Blismas et al., 2009; Lau, 2011) |
| 42 | Proper maintenance and upkeep of modules and building systems | (Blismas et al., 2009; Velarde et al., 2009) |
| 43 | Adequate provision for user comfort and convenience, such as HVAC systems and smart home technologies | (Blismas et al., 2009; Gosling et al., 2016) |
| 44 | Effective community engagement and public relations efforts | (Freund, 1988) |

- | | | |
|----|---|---|
| 45 | Effective collaboration between stakeholders, including designers, builders, and clients | (Abdelmageed & Zayed, 2020; Ali et al., 2023; Blismas et al., 2009; Choi et al., n.d.; A. Gibb, 2001b; Jung et al., 2021a; Lau, 2011; L. Li, Li, Guangdong, et al., 2018; O'Connor et al., 2014a; Shash et al., 2020) |
| 46 | Use of sustainable and resilient building practices to withstand natural disasters and climate change impacts | (C. T. Haas et al., 2002; Lau, 2011) |
| 47 | Adequate training and certification for factory workers and on-site assembly crews | (Sabharwal et al., 2009; Youdale, 2009) |
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Modular of housing literature has been reviewed from specific aspects, such as the mass of housing (Abdulmajeed et al., 2022), critical success factor (Wuni et al., 2019, 2020), Critical success factor for Optimum and Maximum Industrial Modularization (O'Connor et al., 2014c), critical success factors for the project planning (L. Li, Li, Wu, et al., 2018b), Off-site manufacture in Australia: Current state and future directions (Nick Blismas, 2007), identification and prioritization of success factor (Jung et al., 2021a), its application in modern construction methods in Saudi Arabia (Shash et al., 2020), as well as its overall performance in particular areas. Based on existing literature, no previous studies have focused on the CSFs related to a specific stage of the modular process.

This research aims to address this gap by using a stage gate model to identify and understand the CSFs for implementing modular housing in Saudi Arabia. The model will define gates that outline the relevant factors for each stage of the modular process, from planning to assembly on site, and allocate them accordingly. In examining CSFs for modular housing, literature highlights several pivotal components—design standardization, effective project management, stakeholder engagement, quality control,

supply chain management, and regulatory compliance—as instrumental in steering Modular housing projects toward success. These elements have been consistently identified as crucial for ensuring projects are delivered on time, within budget, and to the desired quality. Despite the recognition of these factors, there is a discernible gap in the literature regarding a comprehensive examination of their hierarchical importance and interconnectivity, especially within the context of Saudi Arabia's unique construction landscape. This omission underscores an urgent need for research focused on not just identifying but also critically analyzing and ranking these CSFs according to their significance in the Saudi Arabian modular housing sector. The Stage-Gate Success Model offers a robust framework that can fill the gap in the research on critical success factors of modular housing. By integrating the Stage-Gate Success Model, this research aims to provide a holistic understanding of the critical success factors and their interdependencies in the context of modular housing, ultimately contributing to more successful implementation and improved outcomes in the industry.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter outlines the methodological framework employed to investigate the critical success factors for modular housing in Saudi Arabia. It combines structured surveys with expert interviews to gather nuanced insights into the industry's perspectives on critical success factors. This chapter also addresses the sample and population summary. The data collection section describes the process of conducting a literature review and a pilot study to refine the list of critical success factors. Subsequent sections delve into the reliability and normality tests, followed by a detailed explanation of the Kruskal-Wallis test and PCA. The chapter then transitions into characterizing the critical success factors, integrating findings to develop a nuanced a stage-gate success factors model that categorizes the factors across different project stages. Concluding, the chapter discusses the validation of the a stage-gate success factors model.

3.2 RESEARCH DESIGN

This research adopts a mixed-method research design summarized in figure1 to explore and analyze the CSFs for modular housing projects in Saudi Arabia. This approach combines quantitative and qualitative methods, enabling a comprehensive understanding of the research problem. The quantitative component involves a structured survey, designed to systematically gather data on the perceptions and priorities of industry professionals regarding CSFs as detailed in Figure 1.

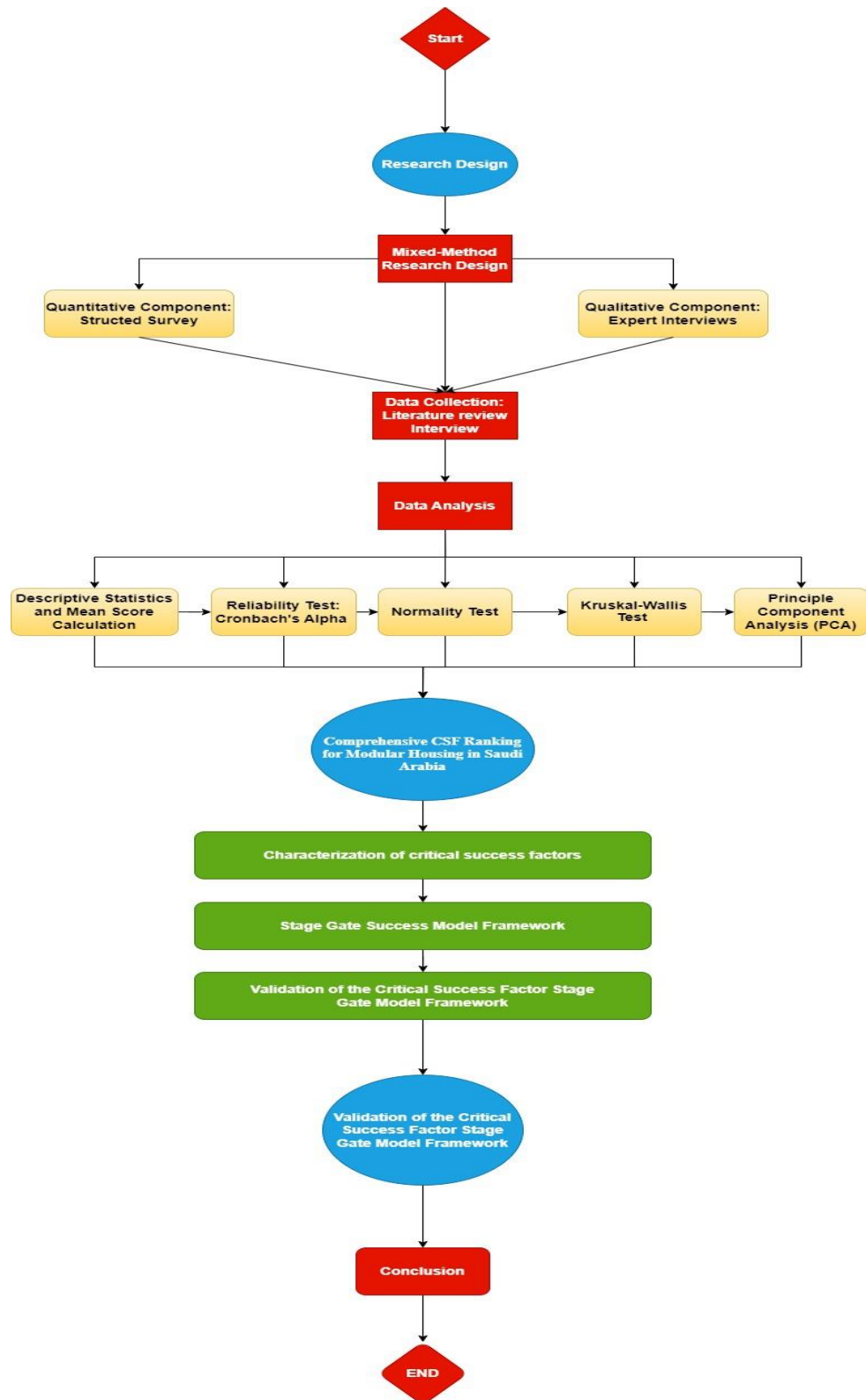


Figure 3.2 Research Methodology

qualitative component, on the other hand, includes conducting interviews with subject-matter experts to refine and validate the questionnaire questions. The rationale behind choosing a mixed-method approach lies in its ability to provide a holistic view of the research problem. While the quantitative method allows for the collection of empirical data and generalization of results, the qualitative method offers insights into the nuances and in the context of Saudi Arabia's modular housing industry. This combination ensures that the research findings are robust, well-rounded, and reflective of the multifaceted nature of the industry.

3.3 SURVEY DESIGN AND INSTRUMENTATION

Four questionnaires were designed in this study. The first survey was a pilot study questionnaire is to get the opinion and feedback about the CSF from the professional of Modular housing in Saudi industry. This questionnaire has two parts (see **Appendix A**). part one for the background information to the respondent. Part two for the rating the CSF based on the contribution of the factors in Saudi Arabia and in this section is require removing and add factors that may be not cover in the study. The goal of this survey is to refine and clarity of each success factors of modular housing within the Saudi Arabian context and their contributions in the industry. The second survey was designed to rank the CSF and their implementation in Saudi Arabia. the second had the same distribution of the sections (see **Appendix B**). Part two requires the respondent to evaluate the significance of CSFs for modular housing project, on 5-point Liker scale, respectively. The core of this survey involves ranking the critical success factors of modular housing Saudi Arabia.

The third survey was designed to categorize the CSFs into five stages from planning until onsite assembly. The second section of the survey (see **Appendix C**) requested to allocate

and classify these CSFs into five primary stages and in this section the respondent had the flexibility to apply the same factors into multiple stages. The fourth questionnaire was designed to validate the stage gate model with real case study of modular housing in Saudi Arabia, in this survey was just targeting the directors of the four projects. Part two in this survey (see **Appendix D**) is requesting from the director of the project to evaluate every CSFs of modular housing and how this factor was be implemented in their project. Outcome of the validation survey were used to revise the stage gate model within the modular housing real projects in Saudi.

The survey design and instrumentation segment is a critical component of the research methodology for collecting quantitative data pertinent to the CSFs in modular housing. The survey is structured into three main parts including, introductory, demographic information, and CSFs evaluation.

Introductory section: underscores the importance of each response in contributing to the research's overall goals. It reassures respondents about the confidentiality of their answers, thereby encouraging transparency and honesty in their responses. Furthermore, it includes concise instructions on how to navigate the questionnaire, ensuring that participants are well-informed about the process, which, in turn, enhances the quality and reliability of the data collected.

Demographic information section: This segment of the survey is instrumental in gathering demographic information about the respondents. By capturing data on the respondents' professional roles, years of experience in the industry, and their specific involvement in modular housing projects, this section enables the research to contextualize the findings.

The demographic information is through understanding the background of each respondent that the research can draw more targeted and meaningful conclusions about the CSFs in modular housing.

CSF Evaluation: is dedicated to uncovering the perceived importance of each identified Critical Success Factor. Respondents are asked to assess the importance of each factor to the success of modular housing projects using a 5-point Likert scale. This scale, which ranges from "Very Insignificant" to "Very Significant," is chosen for its ability to capture varying degrees of importance across a spectrum, thereby providing a nuanced understanding of each factor's perceived value .The delineation of the sample and population summary is pivotal in understanding the breadth and depth of insights gathered in the research regarding the modular housing sector in Saudi Arabia. By engaging with a diverse group of industry professionals through a meticulously designed sampling strategy, the research aimed to garner a comprehensive understanding of the CSFs) crucial for the success of modular housing projects for creation the stage gate model framework.

The research's population of interest encompassed a broad spectrum of professionals actively involved in the modular housing sector within Saudi Arabia. This included architects, engineers, project managers, suppliers, and policymakers, among others. The inclusion of a wide range of professional roles and expertise areas was crucial for capturing the multifaceted nature of CSFs in the modular housing sector, ensuring that the research's findings were grounded in the practical realities and challenges faced by industry practitioners. The final sample consisted of 58 respondents, mirroring the diversity within the modular housing sector in terms of professional roles and experiences. The survey's reach extended across 15 cities, achieving comprehensive geographic coverage, and

ensuring that the insights gathered were representative of the modular housing landscape across the entire Saudi Arabia. This extensive reach was essential for capturing the regional nuances and variations in CSFs, thereby enriching the research's data with a broad spectrum of perspectives.

3.4 PILOT STUDY

A pilot study was conducted as a foundational step to refine the list of CSFs for modular housing projects in Saudi Arabia. Engaging 10 experienced engineers from prominent modular housing factories in Saudi Arabia, the study aimed to validate the relevance and clarity of the initially identified CSFs and to know what the exact factors are that contribute within the Saudi Arabia modular housing industry. Through structured interviews, participants provided invaluable feedback on the applicability, redundancy, and clarity of each factor. This process ensured that the survey instrument was not only methodologically sound but also tailored to the unique industry practices and regulations of Saudi Arabia

3.5 DATA COLLECTION

The data collection process for this research involves conducting a comprehensive literature review to gather relevant information on the critical success factors of modular housing. The literature review serves as a valuable source of knowledge, providing insights, theories, and empirical findings from previous studies conducted in the field. The first step in the data collection process is to identify and select relevant literature sources. This involves conducting systematic searches in academic databases, journals, conference proceedings, books, and reputable online sources. Keywords such as "modular housing," "prefabricated construction," "critical success factors," "project success," and related terms will be used to retrieve relevant articles. Thematic analysis will be conducted to identify

recurring themes, patterns, and trends within the literature. Thematic analysis allows for a comprehensive understanding of the critical success factors and their interrelationships. The collected literature will be analyzed to identify any gaps or areas of limited research within the field of critical success factors of modular housing. These gaps in existing research present valuable opportunities for further investigation, ultimately contributing to the expansion of knowledge in the field.

Following the extensive literature review, structured interviews will be conducted with key stakeholders in the modular housing industry in Saudi Arabia, including project managers, engineers, and other professionals directly involved in Modular housing projects. These interviews are designed to capture in-depth insights and practical experiences, supplementing the theoretical and empirical data derived from the literature review. The identified critical success factors and their associated dimensions will inform the development of research survey questions, and data analysis approaches. The literature review serves as a basis for further data collection and analysis, enabling a comprehensive investigation into the critical success factors of modular housing in Saudi Arabia.

3.6 DATA ANALYSIS

The data analysis phase constitutes a crucial component of the research process, serving as the foundation upon which the study's conclusions are drawn. This phase employed a strategic array of statistical tests. These tests were meticulously chosen based on their capacity to analyze the survey data effectively, allowing for a nuanced understanding of the CSFs' significance and impact. This section delves into the data analysis strategies employed, highlighting the selection of specific statistical tests and their roles in facilitating a comprehensive evaluation of the CSFs. Google forms was used as the tool for

questionnaire design and once the number of responses was satisfied, the descriptive statistics and the other tests were applied to the data collected with the help of the IBM software SPSS

3.7 DESCRIPTIVE STATISTICS

In the analytical framework of this research focusing on the CSFs for modular housing in Saudi Arabia, the employment of descriptive statistics and mean score calculation plays a foundational role. This statistical approach is instrumental in offering a granular understanding of the data's central tendencies, dispersion, and the relative importance of each CSF as perceived by industry professionals. The calculation of descriptive statistics marks the initial phase of data analysis, providing a snapshot of the data collected through the survey. The mean offers a straightforward measure of central tendency, indicating the overall direction in which respondents' opinions lean. The mean is given by Equation (1) (Ross, 2017):

$$\mu = \frac{(\sum X_i)}{N} \quad (1)$$

Where X_i denotes the individual ratings for each CSF and N represents the total number of responses. The standard deviation measures the dispersion or variability in the ratings for each CSF. It is calculated using the formula (2) (Ross, 2017):

$$\sigma = \sqrt{\frac{(\sum X_i - \mu)^2}{N}} \quad (2)$$

where (X_i) is each rating, (μ) is the mean of the ratings, and (n) is the total number of ratings. This statistic helps in understanding how spread out the ratings are around the mean, providing insights into the consensus among respondents regarding each CSF's importance. Following the computation of descriptive statistics, the mean score for each CSF is analyzed to determine its average importance rating as provided by the survey respondents. This method enables the initial ranking of the CSFs according to their perceived importance. By quantifying the average rating assigned to each factor, the analysis facilitates a clear, prioritized list of CSFs, reflecting the collective judgment of industry professionals on what contributes most significantly to the success of modular housing projects.

3.8 RELIABILITY TEST

The Reliability Test, particularly through the calculation of Cronbach's Alpha (α), is a crucial step in the research process, serving as a measure of the internal consistency and reliability of the survey instrument used in assessing CSFs for modular housing in Saudi Arabia. This statistical test evaluates the degree to which related items within a survey are consistent in their measurement and how well they represent the underlying concept being investigated. This section elaborates on the methodology of the Cronbach's Alpha test, its calculation, and its significance in the context of this study. Cronbach's Alpha is calculated to determine the internal consistency or reliability of the survey items related to CSFs, (Hulin et al., 2001).

$$r_{11} = \left[\frac{k}{(k-1)} \right] \left[1 - \frac{\sum \sigma_b^2}{\sigma_t^2} \right] \quad (3)$$

Where N is the number of survey items CSFs being evaluated, σ_b^2 represents the average covariance among the item pairs, and σ_t^2 denotes the average variance across all survey items. A high value of Cronbach's Alpha suggests that the survey items exhibit a high level of internal consistency, indicating that they are reliably measuring the same underlying concept. Typically, an α value of 0.7 or above is considered acceptable in social science research, though higher values are preferable, especially in contexts where precise measurement is critical (Hulin et al., 2001). The computation of Cronbach's Alpha ensures that the CSFs identified through the survey are consistently understood and evaluated by different respondents. This reliability is vital for the integrity of the research's findings. By assessing the internal consistency of the survey instrument, Cronbach's Alpha serves as a form of validation. It confirms that the survey items collectively form a coherent measure of the concept of interest, in this case, the CSFs for modular housing (Tavakol et al., 2011).

3.9 RANKING OF CRITICAL SUCCESS FACTORS

The Relative Importance Index (RII) serves as a pivotal analytical tool within the research framework, especially in studies aimed at evaluating the significance of various elements. The RII method quantitatively measures the relative priority of each factor based on the perceptions of the survey respondents. This section details the methodology behind RII, its calculation, and its significance in the context of this research. The RII is calculated to provide a normalized score that reflects the relative importance of each CSF as perceived by the participants of the research. The calculation of RII is based on Equation (4) (Azman et al., 2019).

$$RII = \frac{\sum w_i}{A \times N} \quad (4)$$

Where w is the sum of the weights assigned by the respondents to each CSF. These weights correspond to the Likert scale ratings (e.g., 1 for 'Very Insignificant' to 5 for 'Very Significant'). A is the highest weight on the scale (e.g., 5 in a 5-point Likert scale). N is the total number of responses for each factor. The RII values range from 0 to 1, with higher values indicating greater importance or significance as attributed by the survey respondents. This index allows for the ranking of the CSFs in descending order of importance, providing clear guidance on which factors are considered most critical by industry professionals (Azman et al., 2019). In addition, RII method facilitates a straightforward prioritization of CSFs based on empirical data. By quantifying the level of importance attributed to each factor, the study can precisely identify which CSFs are deemed most vital for the success of modular housing projects.

3.10 NORMALITY TEST

The normality test constitutes a fundamental preliminary step in the statistical analysis process, especially within research studies that aim to explore complex phenomena such as the CSFs for modular housing in Saudi Arabia. This test is instrumental in determining the distribution pattern of the dataset, which in turn influences the selection of appropriate statistical methods for further analysis. Among the various techniques available for assessing normality, the Shapiro-Wilk test is commonly employed due to their robustness and reliability. The Shapiro-Wilk test are statistical procedures used to evaluate whether a dataset follows a normal distribution. The Shapiro-Wilk test is particularly effective for small to medium-sized datasets, offering high sensitivity to deviations from normality.

The outcome of the normality test informs the researcher's choice between parametric and non-parametric tests. If the data distribution significantly deviates from normality, non-parametric methods may be more appropriate, as they do not assume a specific distribution shape. In cases where the data do not meet the normality assumption, researchers may consider data transformation techniques to approximate normality (Ghasemi et al., 2012). This enhances the applicability of parametric tests and the reliability of their results. Understanding the distribution of the dataset facilitates a more nuanced interpretation of the statistical findings. It allows researchers to contextualize their results within the framework of distribution characteristics, adding depth to the analysis (King et al., 2019).

3.11 KRUSKAL-WALLIS TEST

The Kruskal-Wallis test plays an important role in the analysis of CSFs for modular housing in Saudi Arabia. As a non-parametric method, it is designed to test for differences across multiple groups without relying on the normal distribution assumption, making it an indispensable tool in the researcher's statistical method (Jhade et al., 2023). The Kruskal-Wallis test extends the Mann-Whitney U test to more than two groups, comparing medians among multiple independent samples to assess if they come from the same distribution. The test statistic (H) is calculated using Equation (5) ("Kruskal-Wallis Test," 2008).

$$H = \frac{(N-1) * (\sum (n_i * R_i^2) - 3(N+1))}{\sum n_i (R_i^2)} \quad (5)$$

Where N represents the total number of observations across all groups, while n_i denotes the number of observations in group i . The term R_i corresponds to the rank sum or mean rank for group i , which is the sum of the ranks assigned to all values within that group. The summation symbol ($\sum$) indicates that the equation sums values across all groups. For

this research, the Kruskal-Wallis's test was employed to evaluate the CSFs for modular housing. This involved grouping the CSFs based on certain classifications (e.g., planning, design, manufacture, transportation, and assembly) and then applying the test to determine if there were statistically significant differences in how these groups of CSFs were ranked in terms of importance by the survey respondents. The Kruskal-Wallis test is particularly valuable for identifying which groups of CSFs differ significantly in their rankings. This insight is pivotal for understanding how different aspects of modular housing are prioritized by professionals across the sector ("Kruskal-Wallis Test," 2008).

3.12 PRINCIPLE COMPONENT ANALYSIS (PCA)

For analyzing the CSFs of modular housing projects in Saudi Arabia, Principal Component Analysis (PCA) is proposed as a robust statistical tool. Although, Relative Importance Index (RII) method is commonly used method, but it has its own limitations (Johnson et al., 2004), however, PCA is more suitable for complex and high dimensional data (L. C. Lee et al., 2021). Considering that our study involves 38 CSFs and the study intends to select top 10 CSFs so the purpose of the study becomes dimensionality reduction we prefer PCA over RII, however, we drive a comparison of both methods in this study. PCA is utilized to reduce the dimensionality of the dataset while retaining the most significant variance present in the data related to CSFs. This technique identifies principal components that explain the maximum amount of variance, enabling a more nuanced understanding of the underlying patterns influencing project success.

This method involves constructing a correlation or covariance matrix from standardized data, followed by extraction and rotation of the principal components. Each component derived from the PCA represents a combination of CSFs that together capture the most

significant variations in the data. This approach helps in visualizing the influence of each factor across different project phases, providing strategic insights into their prioritization and management. The application of PCA in this context addresses the limitations of RII by offering a more comprehensive analysis that considers interactions between multiple factors, rather than assessing them in isolation. This enables a deeper exploration of how various CSFs interrelate and impact the overall project effectiveness, facilitating more informed decision-making and strategic planning in the modular housing industry.

3.13 STAGE-GATE MODEL DEVELOPMENT

The development of stage-gate model for modular housing in Saudi Arabia represents a significant advancement in project management methodologies within the construction industry. This research synthesizes quantitative feedback from 58 industry professionals and qualitative insights from 10 experts in crucial areas such as planning, contracts, production, and design. For this purpose, the second questionnaire was designed (see **Appendix C**) to categorize the CSFs into the five preliminary stages, and the expert have the flexibility to distribute the same factor in multiple stages. The innovative approach adopted in this study combines empirical data and expert evaluations to enrich the understanding of CSFs for modular housing projects.

In developing a stage-gate success factors model for modular housing in Saudi Arabia, this research aligns with established methodologies that have demonstrated success across various industries. The adoption of a structured stage-gate process is supported by (R. G. Cooper, 1990), who introduced stage-gate systems as effective tools for managing new products, underscoring their utility in enhancing decision-making and streamlining project management. This approach has been validated in risk control system for liquefied natural

gas plant projects, with (Jang et al., 2015) emphasizing the importance of systems approaches to design phase which is integral to the successful implementation of modular housing projects. Furthermore, the practical application of a formalized stage-gate process in R&D and Innovation Projects, as discussed by (Johannesson, 2016), provides a case study on its efficacy in improving project outcomes, mirroring the objectives of this research in the context of Saudi Arabia's modular housing industry. Also, another studies by (Wuni et al., 2020b) who develop stage gate model frame work of CSF and their implementation of modular integrated construction, another study is A stage-gate model for MiC implementation decision-making (Wuni et al., 2022). These references collectively reinforce the methodological framework employed in this study, illustrating its relevance and potential for contributing significant insights to the field of modular housing.

The development of the stage-gate model stands out as a cornerstone of this research, offering a phased categorization that acts as a sequential roadmap for project managers and stakeholders. This model highlights essential considerations at each project stage, facilitating strategic planning and serving as an invaluable tool for risk management. By ensuring that pivotal factors are addressed throughout the project's lifecycle, the model aids in navigating the complexities of modular housing projects, enhancing efficiency and success rates. The integration of categorization into the broader methodological framework of the research represents a significant stride in research design. This approach not only deepens the quantitative findings but also amplifies the qualitative insights, resulting in a comprehensive view of the CSFs. Such methodological sophistication enables the research

to achieve a holistic understanding of the elements critical to the success of modular housing projects, particularly within the distinct context of Saudi Arabia.

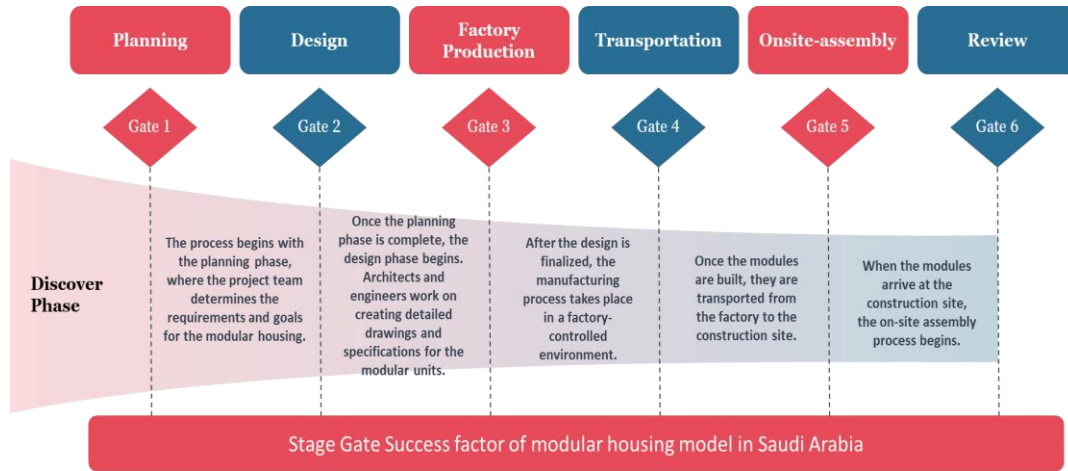


Figure 3.13 Stage Gate Success factor For Modular Housing

This multi- faceted analysis, rooted in both empirical data and expert knowledge, paves the way for significant advancements in modular housing.

3.14 VALIDATION OF CSFs STAGE GATE MODEL

The validation of a stage-gate success factors model for modular housing within the Saudi Arabian context is a crucial step towards establishing its relevance and applicability in guiding successful housing projects. This validation process leverages both quantitative and qualitative methodologies to ensure a comprehensive assessment of the framework against the backdrop of real-world modular housing developments. A structured questionnaire was designed (see **Appendix D**) to gather targeted feedback from a directors of large-scale modular housing projects in Saudi Arabia. This group was specifically chosen because of their strategic insight and decision-making authority in large residential projects, making their input invaluable in assessing the practicality and impact of the CSFs identified. The questionnaire was distributed among directors involved in several

significant residential modular housing projects. These projects were meticulously selected based on their scale, impact, and representation of diverse challenges and successes in the modular housing sector within the region.

These interviews aim to delve deeper into the operationalization of the success factors identified by the framework, examining how they are integrated and managed across different stages of project development. The qualitative insights gleaned from these discussions shed light on the practical deployment, challenges, and nuances of implementing the CSFs in real-world projects. This qualitative dimension enriches the validation process, providing context and depth to the quantitative findings and ensuring a holistic understanding of the framework's applicability. By collating and interpreting findings from both the questionnaire and interviews, the research assesses the framework's effectiveness in capturing the critical elements essential for the success of modular housing projects in Saudi Arabia. This dual-faceted validation process enables the refinement of the CSFs, ensuring they are representative of both strategic priorities and the operational realities on the ground.

CHAPTER 4

RESULTS AND DISSCUTION

4.1INTRODUCTION

This chapter explores the CSFs crucial for the development of modular housing in Saudi Arabia, informed by a comprehensive survey of industry professionals. These professionals, with experience ranging from under five to over twenty years and primarily from consultancy and contracting sectors, provide varied and insightful perspectives vital for understanding industry trends and essential elements. After end with the semi structured interview a detailed quantitative analysis has highlighted 38 CSFs, each rigorously validated and demonstrating high internal consistency, as indicated by Cronbach's Alpha. The chapter will delve into these factors, particularly focusing on those deemed most important, such as Adequate Planning and Design, Effective Project Management, and Skilled Labor Utilization, which are vital for the success of modular housing projects.

The upcoming sections will detail (CSF's) for modular housing in Saudi Arabia, using statistics and analyses to outline current trends and future directions. The "Characterization of CSF's" and "Validation of the Critical Success Factor Stage Gate Model Framework" sections will discuss the development and empirical testing of CSFs. These sections cover interviews with ten experts to refine CSFs, contributing to a model that guides the project lifecycle. Additionally, the use of the RII method across four major projects will

demonstrate the model's effectiveness in managing modular housing projects from conception through assembly.

4.2 SURVEY RESULT

The survey is designed to identify and prioritize CSF's for modular housing in Saudi Arabia was responded to by 58 professionals summarized in Table 3, representing a rich diversity in professional backgrounds and geographical locations. This diversity enhances the depth and reliability of the findings, providing a comprehensive view of the modular housing sector across Saudi Arabia. Moreover, the professional affiliations of the respondents, predominantly from consultancy and contracting sectors, add a multi-dimensional perspective to the analysis. Table 3 outlines the strategic and operational insights gained from such a distribution are invaluable, offering a balanced viewpoint that bridges theory with practice. The depth of experience among the respondents, spanning decades, further solidifies the foundation of this research.

Table 4.2 Survey Respondent

Main adjective	Sub_adjective	Responses	Responses%
Organizational Affiliation	Consultant	37	63.80%
	General Contractor	14	24.10%
	Architect	5	8.60%
	Client Respective	2	3.40%
Professional Experience in Modular housing work	<5years	5	8.60%
	5-10years	16	27.60%
	10-20years	25	43.10%
	>20years	12	20.70%
Education Level	Bachelor's degree	55	94.48%
	Master's in civil	2	3.40%
	Bachelor's degree in architecture	1	1.72%

Most respondents are affiliated with consultancy services (62.1%), followed by general contracting (24.1%). This distribution indicates a significant influence of consultancy and contracting perspectives in the modular housing industry, providing a balanced view that combines both strategic and operational insights. The respondents exhibit a rich tapestry of professional experience, with a substantial portion (43.1%) possessing 10-20 years of experience in modular housing work. This is complemented by those with 5-10 years (27.6%) and more than 20 years (20.7%) of experience, thus ensuring that the survey encapsulates a seasoned understanding of the industry. The survey's participants' involvement in modular housing projects varies, with the majority having engaged in fewer than five projects (63.8%). This is indicative of a burgeoning industry with emerging opportunities and challenges.

4.3 SEMI-STRUCTURED INTERVIEWS

Based on the 10 professionals' engineers' responses from the first questionnaire (see Appendix A) the survey was made to refine the CSFs, and based on RII values certain factors were identified as less relevant or redundant within the specific context of Saudi Arabia the respondent did not adding additional factors just improve and delete. Through semi-structured interviews with stakeholders involved in modular housing in Saudi Arabia, the study critically assessed the relevance of each initially identified CSF. Notably, factors such as insurance coverage, changes in marketing demand, after-sales services, warranties, and advanced building techniques like modular framing and penalization were recommended for removal. The rationale for this recommendation stemmed from their limited direct impact on the immediate success of modular housing projects in the region, or due to their overlap with other, more critical factors. The study also led to a revision in

the descriptions of the remaining CSFs. It was essential that each factor was explicitly contextualized to Saudi Arabia, ensuring that the language used was directly applicable and easily understandable by industry stakeholders. This rephrasing was aimed at making each CSF self-explanatory, capturing the unique aspects of the Saudi market and regulatory environment, thus enhancing the overall clarity and effectiveness of the survey instrument.

The outcome of this process was a more streamlined, relevant, and contextually appropriate set of CSFs for guiding modular housing projects in Saudi Arabia. This ensures that the survey instrument and subsequent research findings are more aligned with the actual needs and conditions of the industry, thereby increasing the utility of the research in practical applications and strategic decision-making within the local context. focusing on refinement rather than expansion, the research provides a clearer, more targeted framework for stakeholders to assess and improve the success rates of modular housing projects in Saudi Arabia. This approach underscores the importance of relevance and specificity in research aimed at practical industry improvements.

4.4 DESCRIPTIVE STATISTIC

The second questionnaire (see Appendix B) of this study focused on ranking the (CSF's) for modular housing projects in Saudi Arabia, yielding responses from a total of 58 industry professionals. Table 5 summarizes the mean scores of the 38 identified CSFs, offering a quantitative narrative of their relative importance. A pivotal observation from the analysis is that all 38 CSFs garnered mean scores surpassing the critical threshold of 3.0. This threshold, set within the context of a 5-point grading scale, underscores the fundamental relevance of each factor in the modular housing sector of Saudi Arabia. The broader range of CSFs identified in this research does not signify an overextension of critical elements;

rather, it reflects the nuanced and multifaceted nature of modular housing projects within the unique socio-economic and environmental fabric of Saudi Arabia. The extensive array of CSFs revealed through this survey is not merely an accumulation of variables but rather a comprehensive framework that assists in delineating bespoke CSFs tailored to specific project types and regional requirements.

4.5 RELIABILITY ANALYSIS

The reliability of the collected data is assessed using the Cronbach model. Table 4 presents the reliability statistics for the survey instrument, which the reliability of a survey instrument measuring CSFs in modular housing.

Table 4.5.1 Reliability Analysis

	Numbers of factors	Cronbach Alpha
Critical success factors	38	0.982

Table 4 displays the internal consistency of the survey instrument used to rank the (CSF's) for modular housing in Saudi Arabia was assessed using Cronbach's Alpha reliability coefficient. The reliability statistics reveal a Cronbach's Alpha value of 0.982. This high alpha value, substantially above the commonly accepted threshold of 0.70, indicates an exceptional level of internal consistency among the survey items (Tavakol et al., 2011). A Cronbach's Alpha implies that the CSF's identified are likely to be conceptually related and that the survey questions are cohesively capturing respondents' perceptions of what constitutes success in modular housing projects.

Table 4.5.2 Descriptive Statistics

No.	Critical Success Factors of modular housing	Mean	Std.Devition	RII	Rank
CSF#1	Adequate Planning and Design to creating modular housing that considers local environmental conditions in Saudi.	4.53	0.82	0.90	1
CSF#2	Effective Project Management , precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape.	4.32	1.04	0.86	4
CSF#3	Skilled and Experienced Labor Force trained in modular housing techniques.	4.24	1.01	0.84	12
CSF#4	Proper factory layout and equipment and Adopting Modern Technologies and Automation.	4.05	0.98	0.81	24
CSF#5	Efficient Transportation and Logistics, selecting optimal factory and storage locations.	4	0.95	0.8	31
CSF#6	High-quality materials and components to guarantee the durability and resilience of modular housing structures.	4.34	0.76	0.86	3
CSF#7	Compliance with Saudi building codes and regulations.	4.25	1.11	0.85	10
CSF#8	Adequate funding and financial planning, budget allocation, contingency provisions.	4.27	0.96	0.85	9
CSF#9	Proper site preparation and foundation work.	4.37	0.95	0.87	2
CSF#10	Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project.	4.32	0.98	0.86	4
CSF#11	Use of sustainable and environmentally friendly materials.	3.98	1.06	0.79	32
CSF#12	Integration with existing infrastructure and utilities such as water, electricity, and transportation networks.	4.31	0.94	0.86	6
CSF#13	Compliance with safety standards and regulations specified by Saudi Arabian authorities.	4.29	0.93	0.85	7
CSF#14		3.86	0.96	0.77	37

	Effective marketing and branding for modular housing projects.				
CSF#15	Availability of reliable suppliers and subcontractors.	4.05	0.98	0.81	24
CSF#16	Use of innovative technologies and processes for the Saudi modular housing industry.	3.81	1.05	0.76	38
CSF#17	Efficient use of space and resources for the functionality of modular housing designs.	3.98	1.01	0.79	32
CSF#18	Effective waste management practices, recycling, responsibly disposing of construction waste.	3.87	0.88	0.77	36
CSF#19	Effective risk management strategies, identify, assess, and mitigate potential challenges and uncertainties in modular housing projects.	4.01	0.99	0.80	29
CSF#20	Flexibility in design and customization options.	3.98	0.92	0.79	32
CSF#21	Adherence to Saudi Health and Hygiene Standards.	4.08	0.97	0.81	20
CSF#22	Optimal energy utilization and conservation efforts.	4.10	0.98	0.82	19
CSF#23	Proper training and development of employees.	4.05	1.05	0.81	24
CSF#24	Effective Use of Data Analytics and General Performance Metrics for Modular Housing Projects in Saudi Arabia.	4.08	1.01	0.81	20
CSF#25	Continuous Research and Development to Maintain Competitive Capability in the Modular Housing Industry in Saudi Arabia.	3.98	0.94	0.79	32
CSF#26	Effective Supply Chain Management in Modular Housing Factories in Saudi Arabia.	4.06	1.02	0.81	22
CSF#27	Timely delivery of modules to site.	4.15	0.93	0.83	16
CSF#28	Efficient assembly and installation of modules on site.	4.22	0.87	0.84	13
CSF#29	Adoption of uniform building components and systems.	4.06	0.91	0.81	22
CSF#30	Proper handling and storage of modules during transportation and on site.	4.29	0.79	0.85	7
CSF#31		4.25	1.03	0.86	10

	Effective insulation and weatherproofing measures.				
CSF#32	Compliance with fire safety regulations.	4.12	1.06	0.82	17
CSF#33	Effective soundproofing and noise reduction measures.	4.03	0.83	0.80	28
CSF#34	Adequate contingency planning and emergency response measures.	4.05	1.06	0.81	24
CSF#35	Proper maintenance and upkeep of modules and building systems.	4.12	1.04	0.82	17
CSF#36	Adequate provision for user comfort and convenience, such as HVAC systems and smart home technologies.	4.22	0.91	0.84	13
CSF#37	Effective collaboration between stakeholders, including designers, builders, and clients.	4.17	1.07	0.83	15
CSF#38	Use of sustainable and resilient building practices to withstand natural disasters and climate change impacts.	4.01	0.96	0.80	29
Weighted mean		4.13			
Standard Deviation			0.75		

Based on the RII in Table 5, the top success factor of modular housing in Saudi Arabia is Adequate Planning and Design to creating modular housing that considers local environmental conditions in Saudi (CSF#1). This factor emerged as the most significant, achieving a mean score of 4.53. Notably, 67.2% of respondents rated it as ‘Very significant.’ This strong endorsement underscores its pivotal role in the successful implementation of modular housing projects. Proper Site Preparation and Foundation Work (CSF#9) was identified as significantly important, with a mean score 4.37. A notable percentage of respondents, 60.30% rated it as ‘Very significant’.

High-quality materials and components to guarantee the durability and resilience of modular housing structures (CSF#6). Resulting in a mean score of 4.34, this factor

highlights the industry's commitment to durability and resilience. A significant 48.3% of participants considered it 'very significant,' reflecting the importance of material quality in ensuring the longevity of modular structures, Effective Project Management, precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape (CSF#2). ranked fourth, with a mean score of 4.32, indicating its substantial importance. About 58.6% of participants considered it 'Very significant,' highlighting the need for precise scheduling and resource allocation in these projects, Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project (CSF#10). With a mean score of 4.32, this factor underscores the need for high-standard quality control. A considerable 58.6% of respondents rated it as 'Very significant,' emphasizing its role in maintaining Saudi standards throughout the project lifecycle. Integration with existing infrastructure and utilities such as water, electricity, and transportation networks (CSF#12) plays a significant role in the successful implementation of modular housing, earning a mean score of 4.31. Over half of the respondents (56.9%) acknowledge its importance as 'Very significant', underscoring the critical nature of seamless integration into the existing urban fabric. Compliance with safety standards and regulations specified by Saudi Arabian authorities (CSF#13) is imperative, reflected by a mean score of 4.29 and rated as 'Very significant' by 48.3% of participants. This factor ensures that modular housing projects adhere to the required safety protocols, which is essential for the wellbeing of occupants and longevity of the structures. Proper handling and storage of modules during transportation and on site (CSF#30) is also crucial, indicated by a mean score of 4.29, with 48.3% rating it 'Very significant'. This factor is key to maintaining the integrity of prefabricated components, ensuring they remain undamaged

and are ready for assembly upon arrival at the construction site. Adequate funding and financial planning, budget allocation, contingency provisions (CSF#8) is recognized for its fundamental role in project success, reflected in a mean score of 4.27 and deemed 'Very significant' by 51.7% of respondents. Proper financial management ensures that projects are completed within budget and are financially viable. Compliance with Saudi building codes and regulations (CSF#7) is another cornerstone, with a mean score of 4.25. It is seen as 'Very significant' by 55.2% of participants, indicating its role in ensuring projects meet national construction and quality standards, which is critical for the approval and sustainability of modular housing projects in the region.

Based on the RII in Figure 3, the top success factor of modular housing in Saudi Arabia is Adequate Planning and Design to creating modular housing that considers local environmental conditions in Saudi as shown in Table 5. Notably, 67.2% of respondents rated it as 'Very significant'. 'This strong endorsement underscores its pivotal role in the successful implementation of modular housing projects. Proper Site Preparation and Foundation Work (CSF#9) was identified as significantly important, with a mean score 4.37. A notable percentage of respondents, 60.30% rated it as 'Very significant'.

High-quality materials and components to guarantee the durability and resilience of modular housing structures (CSF#6). Resulting in a mean score of 4.34, this factor highlights the industry's commitment to durability and resilience. A significant 48.3% of participants considered it 'Very significant,' reflecting the importance of material quality in ensuring the longevity of modular structures, Effective Project Management, precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape (CSF#2). ranked fourth, with a mean score of 4.32, indicating its substantial importance.

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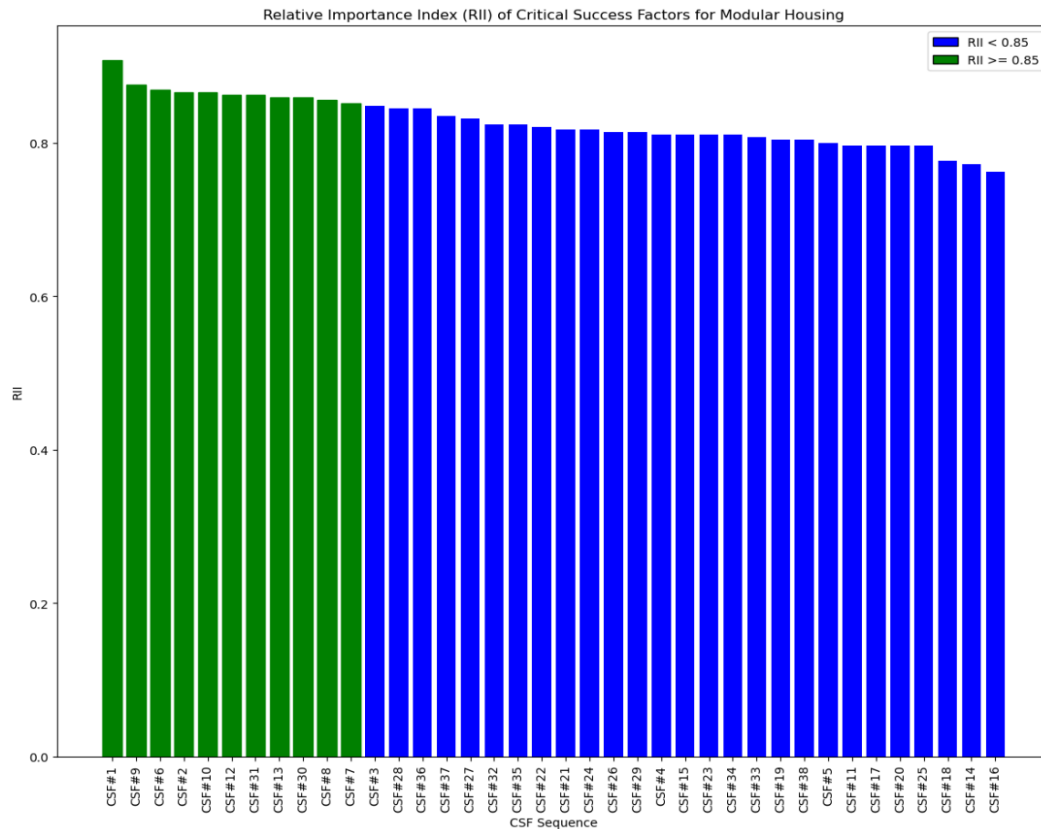


Figure 4.5 Result of RII

The survey's findings on planning and design resonate profoundly with established literature, particularly the works of (Sparkman et al., 1999; Wuni et al., 2019), who emphasize the criticality of these stages in construction projects. This factor's high ranking not only aligns with global trends highlighting the importance of initial planning and design for project success but also reflects specific needs within the Saudi Arabian context. The region's unique climatic and geographical landscape necessitates an approach that is both

adaptable and responsive, consistent with agile methodologies. Planning and design in Saudi Arabia must therefore account for both environmental conditions and cultural appropriateness, underscoring a distinctive regional adaptation of this globally recognized construction principle.

Emphasizing the importance of site preparation and foundation work aligns with (Ofori, 1994) who underline the significance of foundational stages in ensuring construction success. This factor's prominence in the Saudi Arabian might be attributed to the region's diverse environmental conditions, where effective site preparation and foundation work are paramount for structural integrity. The focus on using high-quality materials and components reflects sustainable construction principles advocated by (Ayarkwa et al., 2022; Wuni et al., 2020b) and is indicative of a global shift towards sustainability and quality in construction. In the context of Saudi Arabia, this factor gains additional significance due to environmental challenges. The emphasis on durable and resilient materials aligns with global trends but is particularly relevant in Saudi Arabia, where structures must withstand harsh climatic conditions, demonstrating a region-specific adaptation of a global construction standard.

The emphasis on quality control measures aligns with global construction standards such as ISO 9001 (Jedynak et al., 2019), emphasizing the universal importance of quality management in construction projects. This focus is especially pertinent in the Saudi Arabia, where maintaining high standards is crucial for the success and acceptance of modular housing projects. It reflects not only a commitment to excellence and reliability in the construction industry but also addresses the unique requirements and expectations within

the Saudi Arabian market, making it a region-specific adaptation of a widely recognized construction principle.

The integration of modular housing with existing infrastructure (CSF#12) aligns with the views of (Dimitrijevic, 2013) who stress the importance of such integration in construction projects for the sustainable development of urban areas. Safety compliance (CSF#13) is in harmony with the research of (Okoye et al., 2016), underscoring the necessity of adhering to safety regulations to ensure the well-being of inhabitants and construction workers. The handling and storage of modules (CSF#30) reflect the findings of (Zhang et al., 2021), who suggest proper logistics as crucial for maintaining the quality of prefabricated elements. Financial planning (CSF#8) finds support in the work of (Maddalena, 2012), emphasizing budget management as a cornerstone for project success. Finally, the compliance with building codes (CSF#7) is supported by the findings of (Al-Taie et al., 2014), who acknowledge the importance of regulatory adherence in ensuring the structural integrity and marketability of construction projects.

The top ten CSFs, distinguished by their higher scores, represent the most critical elements deemed essential for the success of modular housing projects in Saudi Arabia. These factors, ranging from robust planning and design to effective project management and quality control measures, highlight the specific areas of focus that industry professionals deem paramount. Conversely, the factors with lower mean scores, while still surpassing the threshold of criticality, offer insights into areas that currently hold lesser priority but are nonetheless integral to the holistic success of modular housing projects in Saudi Arabia.

This expansive identification of CSFs, far from diluting the essence of 'criticality,' provides a more detailed and context-specific roadmap for stakeholders in the modular housing industry. It paves the way for a nuanced understanding and strategic approach towards project implementation in a region that is rapidly evolving and embracing innovative construction methodologies.

4.6NORMALITY TEST

Table 6 outline the administration of the Kolmogorov-Smirnov test on the dataset , provided a robust methodological approach for evaluating the distribution characteristics of the responses associated with each CSF. The p-values are high than the standard alpha level of 0.05, it indicates that there is not enough evidence to reject the null hypothesis. The null hypothesis typically states that the data follows a normal distribution. Therefore, a high p-value greater than significance level of 5% (i.e., $\alpha=0.05$, single-tailed) suggests that the data is likely to be normally distributed.

Table 4.6 Normality Test

sequence	Critical success factors	Kolmogorov-Smirnova Statistic
CSF#1	Adequate Planning and Design to creating modular housing that considers local environmental conditions in Saudi.	0.387
CSF#2	Effective Project Management, precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape.	0.325
CSF#3	Skilled and Experienced Labor Force trained in modular housing techniques.	0.290
CSF#4	Proper factory layout and equipment and Adopting Modern Technologies and Automation.	0.230
CSF#5	Efficient Transportation and Logistics, selecting optimal factory and storage locations.	0.232
CSF#6	High-quality materials and components to guarantee the durability and resilience of modular housing structures.	0.288

CSF#7	Compliance with Saudi building codes and regulations.	0.298
CSF#8	Adequate funding and financial planning, budget allocation, contingency provisions.	0.290
CSF#9	Proper site preparation and foundation work.	0.346
CSF#10	Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project.	0.340
CSF#11	Use of sustainable and environmentally friendly materials.	0.248
CSF#12	Integration with existing infrastructure and utilities such as water, electricity, and transportation networks.	0.337
CSF#13	Compliance with safety standards and regulations specified by Saudi Arabian authorities.	0.291
CSF#14	Effective marketing and branding for modular housing projects.	0.281
CSF#15	Availability of reliable suppliers and subcontractors.	0.307
CSF#16	Use of innovative technologies and processes for the Saudi modular housing industry.	0.227
CSF#17	Efficient use of space and resources for the functionality of modular housing designs.	0.221
CSF#18	Effective waste management practices, recycling, responsibly disposing of construction waste.	0.244
CSF#19	Effective risk management strategies, identify, assess, and mitigate potential challenges and uncertainties in modular housing projects.	0.269
CSF#20	Flexibility in design and customization options.	0.249
CSF#21	Adherence to Saudi Health and Hygiene Standards.	0.258
CSF#22	Optimal energy utilization and conservation efforts.	0.250
CSF#23	Proper training and development of employees.	0.239
CSF#24	Effective Use of Data Analytics and General Performance Metrics for Modular Housing Projects in Saudi Arabia.	0.247
CSF#25	Continuous Research and Development to Maintain Competitive Capability in the Modular Housing Industry in Saudi Arabia.	0.266
CSF#26	Effective Supply Chain Management in Modular Housing Factories in Saudi Arabia.	0.232
CSF#27	Timely delivery of modules to site.	0.248
CSF#28	Efficient assembly and installation of modules on site.	0.277
CSF#29	Adoption of uniform building components and systems.	0.246
CSF#30	Proper handling and storage of modules during transportation and on site.	0.296
CSF#31	Effective insulation and weatherproofing measures.	0.297
CSF#32	Compliance with fire safety regulations.	0.279
CSF#33	Effective soundproofing and noise reduction measures.	0.225
CSF#34	Adequate contingency planning and emergency response measures.	0.244

CSF#35	Proper maintenance and upkeep of modules and building systems.	0.248
CSF#36	Adequate provision for user comfort and convenience, such as HVAC systems and smart home technologies.	0.284
CSF#37	Effective collaboration between stakeholders, including designers, builders, and clients.	0.279
CSF#38	Use of sustainable and resilient building practices to withstand natural disasters and climate change impacts.	0.269

The study's findings illustrate a diverse constellation of CSFs, markedly more extensive than the traditional confines of factors typically noted in the literature. This breadth is reflective of the intricate and multifaceted ecosystem of the modular housing industry in Saudi Arabia. The robust enumeration of CSFs acts as a multi-dimensional matrix, providing a granular and nuanced compass to guide the identification and prioritization of success factors tailored to specific project typologies and regional particularities. As such, the non-normality in the distribution of responses does not diminish the utility of the CSFs identified; rather, it accentuates the individuality and specificity of the modular housing sector in Saudi Arabia.

4.7 KRUSKAL-WALLIS TEST

In examining the CSs for modular housing in Saudi Arabia, an Independent-Samples Kruskal-Wallis Test was performed to rank these factors based on their perceived contribution to the industry summarized in Table 7. The Kruskal-Wallis Test, a non-parametric method, was deemed appropriate due to the ordinal nature of the ranking data.

Table 4.7 Kruskal Wallis Test

Independent-Samples Kruskal-Wallis	
Test Statistic	80.147 ^a
Degree Of Freedom	37
Asymptotic Sig.(2-sided test)	5.09E-05

Table 7 explained the test yielded a chi-squared statistic of 80.147. and asymptotic significance (2-sided) was found to be less than 0.001. This result suggests that there are statistically significant differences in the rankings of the (CSF's) amongst the respondents. Given the significance level (p-value) is below the conventional alpha level of 0.05, we reject the null hypothesis that all groups' CSFs have the same median ranking. The statistically significant result of the Kruskal-Wallis test indicates that not all (CSF's) are regarded equally by industry stakeholders. This implies the presence of a hierarchy among the factors, with certain CSFs holding more weight in contributing to the success of modular housing within the Saudi Arabian context.

4.8 PRINCIPAL COMPONENT ANALYSIS (PCA)

The Principal Component Analysis (PCA) on the CSFs for modular housing in Saudi Arabia offers a nuanced understanding of the factors that are paramount in optimizing project outcomes. The analysis highlights that the factor 'Adequate Planning and Design to creating modular housing that considers local environmental conditions in Saudi' is the most significant in all analysis method, explaining approximately 60.93% of the variance, indicating its pivotal role in the success of modular housing projects. This aligns with

studies emphasizing the criticality of thorough planning and context-specific designs in construction. This aligns with studies emphasizing the criticality of thorough planning and context-specific designs in construction. Interestingly the result for the most important CSF is the same as the results of RII shown in Figure 4.

Table 4.8 Principal Component Analysis (PCA)

CSFs	Critical Success Factors	PCA Score
PC1	Adequate Planning and Design to creating modular housing that considers local environmental conditions in Saudi.	0.161
PC27	Timely delivery of modules to site.	0.1419
PC21	Adherence to Saudi Health and Hygiene Standards.	0.1413
PC6	High-quality materials and components to guarantee the durability and resilience of modular housing structures.	0.1411
PC28	Efficient assembly and installation of modules on site.	0.1395
PC2	Effective Project Management, precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape.	0.1391
PC18	Effective waste management practices, recycling, responsibly disposing of construction waste.	0.1384
PC4	Proper factory layout and equipment and Adopting Modern Technologies and Automation.	0.1376
PC15	Availability of reliable suppliers and subcontractors.	0.1372
PC5	Efficient Transportation and Logistics, selecting optimal factory and storage locations.	0.1370
PC30	Proper handling and storage of modules during transportation and on site.	0.1364
PC13	Compliance with safety standards and regulations specified by Saudi Arabian authorities.	0.1356
PC11	Use of sustainable and environmentally friendly materials.	0.1349

PC10	Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project.	0.1344
PC22	Optimal energy utilization and conservation efforts.	0.1335
PC14	Effective marketing and branding for modular housing projects.	0.1335
PC16	Use of innovative technologies and processes for the saudi modular housing industry.	0.1333
PC25	Continuous Research and Development to Maintain Competitive Capability in the Modular Housing Industry in Saudi Arabia.	0.1319
PC3	Skilled and Experienced Labor Force trained in modular housing techniques.	0.1318
PC9	Proper site preparation and foundation work.	0.1314
PC38	Use of sustainable and resilient building practices to withstand natural disasters and climate change impacts.	0.1313
PC12	Integration with existing infrastructure and utilities such as water, electricity, and transportation networks.	0.1313
PC32	Compliance with fire safety regulations.	0.1306
PC31	Effective insulation and weatherproofing measures.	0.1305
PC23	Proper training and development of employees.	0.1303
PC8	Adequate funding and financial planning, budget allocation, contingency provisions.	0.1300
PC33	Effective soundproofing and noise reduction measures.	0.1299
PC35	Proper maintenance and upkeep of modules and building systems.	0.12983
PC19	Effective risk management strategies, identify, assess, and mitigate potential challenges and uncertainties in modular housing projects.	0.12980
PC34	Adequate contingency planning and emergency response measures.	0.12929

PC24	Effective Use of Data Analytics and General Performance Metrics for Modular Housing Projects in Saudi Arabia.	0.1279
PC26	Effective Supply Chain Management in Modular Housing Factories in Saudi Arabia.	0.1269
PC7	Compliance with Saudi building codes and regulations.	0.1260
PC20	Flexibility in design and customization options.	0.1255
PC29	Adoption of uniform building components and systems.	0.1240
PC36	Adequate provision for user comfort and convenience, such as HVAC systems and smart home technologies.	0.1225
PC17	Efficient use of space and resources for the functionality of modular housing designs.	0.1198
PC37	Effective collaboration between stakeholders, including designers, builders, and clients.	0.1180

These factors reflect the industry's emphasis on logistical efficiency and compliance with health regulations and ensure the importance of durability and efficient site operations, essential for the longevity and success of construction projects. The CSF #1 is usually the part of planning and highlights the importance of local environment and condition as Saudi Arabia bears the extreme weather conditions specially in summers as was summarized in Figure 4. Adequate planning according to the environmental conditions may result in enhanced durability and sustainability of structure. It may also cover comfort and energy efficiency as well. Local environmental considerations may help in optimizing the resource usage by utilizing the locally sourced materials. It may indirectly impact other CSFs as well. For example, considering CSF#1 will automatically impact CSF #38 which ensures resilience in terms of fighting natural disasters and climate change. Similarly, it may ensure the usage of environmentally friendly materials (CSF #11).

The second most important CSF is timely delivery of modules to site (CSF # 27) it is a success factor related to operations and execution, apparently it looks like a logistics issue however, the delays are usually due to many reasons, for example manufacturing delays, transportation delays, supply chain delays, quality assurance, and weather conditions. It shows that adequate planning according to domestic environmental conditions (CSF # 1) can reduce the risk of delays in terms of weather conditions. Addressing CSF # 27 can impact other CSFs. If the timely delivery of modules is ensured it will partially improve the CSF # 5 (Efficient Transportation and Logistics, selecting optimal factory and storage locations), is directly impacted by CSF # 26 (Effective Supply Chain Management in Modular Housing Factories in Saudi Arabia), and directly impact CSF # 28 (Efficient assembly and installation of modules on site). The third most important factor is related to health and safety, CSF # 21 (Adherence to Saudi Health and Hygiene Standards), this CSF may encompass different aspects, from Occupants' health to air passage through building, indoor air quality, sanitation, and water quality. It is obvious that the health and hygiene standards may vary according to geographic location, domestic weather conditions, and even cultural impact. Again CSF # 21 seems core in nature as it will indirectly impact other CSFs, for example CSF # 10 (Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project), CSF # 11 (Use of sustainable and environmentally friendly materials), CSF # 36 (Adequate provision for user comfort and convenience, such as HVAC systems and smart home technologies).

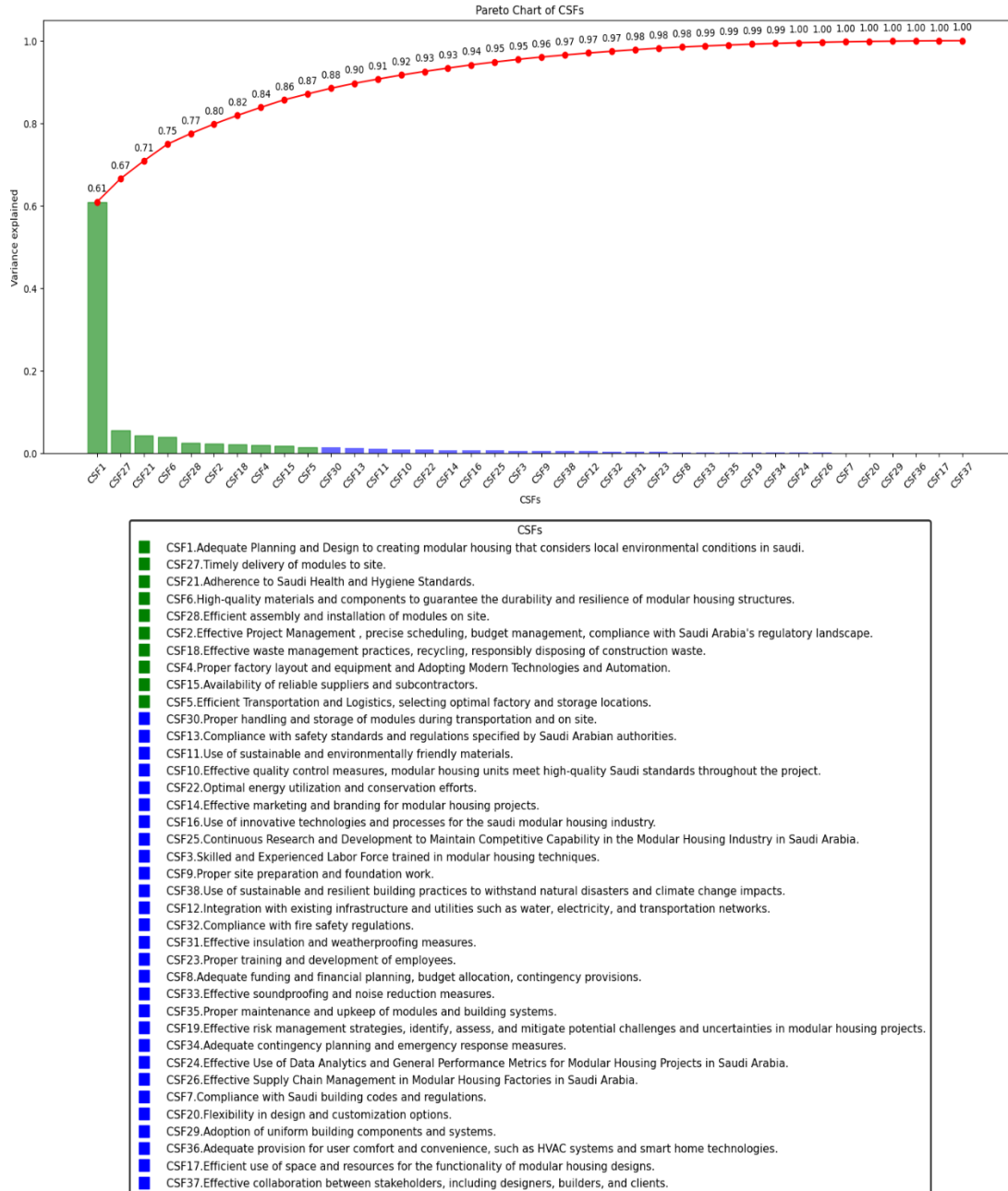


Figure 1.8 Ranking through PCA

The fourth ranked CSF is purely relevant to Quality, CSF # 6 (High-quality materials and components to guarantee the durability and resilience of modular housing structures). Just like the previous top three CSFs, the fourth one is also a core CSF, which may directly or indirectly improve the other CSFs. For example, when selecting for high-quality materials

it is highly abide by CSF # 10 (Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project), CSF # 11(Use of sustainable and environmentally friendly materials), CSF # 13 (Compliance with safety standards and regulations specified by Saudi Arabian authorities) and CSF # 21 (Adherence to Saudi Health and Hygiene Standards). The fifth ranked CSF is CSF #28 (Efficient assembly and installation of modules on site) which again is more of an operational factor and relevant to many other CSFs like CSF # 2, CSF #3, CSF #5, CSF #6, and CSF #7. It employs the top 5 ranked CSFs which explain 80 % of the variance of the data are ranked on top 5 by the experts because they directly or indirectly impact several other SCFs. The relationship of top 5 ranked CSFs with other CSFs is summarized in Figure 5.

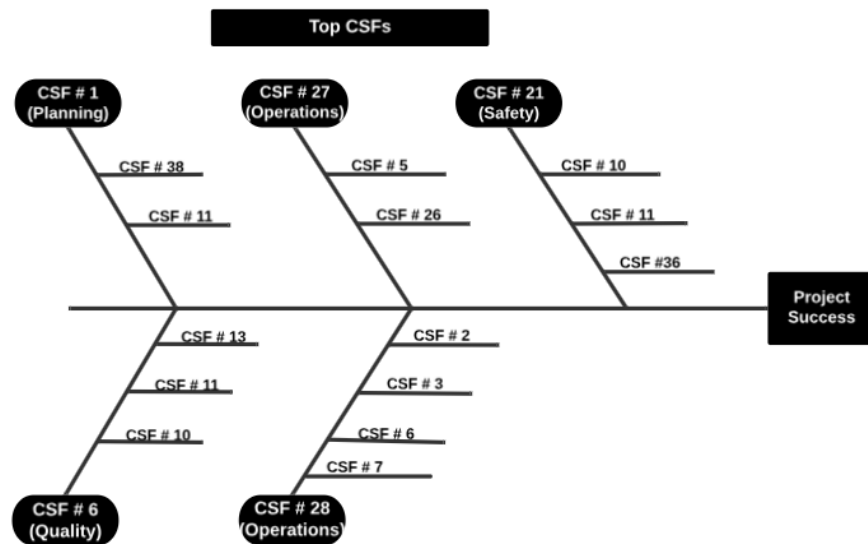


Figure 4.8.2 Top 5 CSFs with their impact on other CSFs

This analysis allows for a more nuanced understanding of the prioritization and interrelation of CSFs, emphasizing the necessity for a strategic approach that accommodates the unique environmental, regulatory, and operational landscapes of Saudi Arabia. The PCA enhances the precision of decision making in project management by

highlighting the most influential factors in a more dimensional space, thereby aiding in the formulation of targeted and effective strategies for the modular housing sector.

4.9A STAGE-GATE CSF's FRAMEWORK

Initially, a third questionnaire was developed (see Appendix C) and distributed to specifically address the task of categorizing the identified CSFs into the preliminary stages of Planning, Design, Manufacture, Transportation, and Assembly. This questionnaire garnered responses from 10 professionals within the modular housing industry in Saudi Arabia, encompassing a range of roles critical to the project lifecycle. These professionals included a manager of planning, director of production, manager of procurement, manager of pricing and contracts, design engineers, and project engineers. Their diverse perspectives were essential for a well-rounded understanding of the CSFs in each project phase. The survey design allowed respondents the flexibility to assign the same CSF to multiple stages of the project lifecycle. In addition to the survey, in-depth interviews were conducted with these experts. These interviews allowed for a richer, more detailed exploration of each CSF's relevance and impact at various stages of the project. This dual approach of surveying and interviewing provided a robust framework for accurately mapping out the CSFs across the project lifecycle, as detailed in Table 9.

In the Planning stage, 22 CSFs are identified, with five factors ranking among the top ten in terms of importance, illustrating the critical nature of initial project planning and its alignment with regulatory and environmental considerations. The Design stage includes 22 CSFs, with five factors within the top ten, reflecting the essential role of design in addressing both aesthetic and functional requirements. Manufacturing, as a pivotal phase in realizing design intentions, encompasses 27 CSFs, six of which are in the top ten,

highlighting the importance of quality control and technological integration. Transportation, critical for the timely and safe delivery of modules, features 13 CSFs, with four among the top ten, underscoring the logistical challenges inherent in Modular housing. Finally, the Assembly phase lists 21 CSFs, five of which rank in the top ten, emphasizing the necessity of precision and coordination in the final construction phase. This structured categorization not only facilitates a nuanced understanding of each phase but also enhances strategic planning and risk management across the project lifecycle as explained in Figure 6.

Table 4.9 Characterizations of the CSF into five phases

n	Critical Success Factor	Planning	Design	Manufacture	Transportation	Assembly	RII	RANK
CSF# 1	Adequate Planning and Design to creating modular housing that considers local environmental conditions in Saudi	✓	✓				0.906	1
CSF# 9	Proper site preparation and foundation work	✓					0.875	2
CSF# 6	High-quality materials and components to guarantee the durability and resilience of modular housing structures.		✓	✓			0.868	3
CSF# 2	Effective Project Management , precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape	✓	✓	✓	✓	✓	0.865	4
CSF# 10	Effective quality control measures, modular housing			✓		✓	0.865	4

	units meet high-quality Saudi standards throughout the project.							
CSF# 12	Integration with existing infrastructure and utilities such as water, electricity, and transportation networks.	✓	✓			✓	0.862	6
CSF# 31	Effective insulation and weatherproofing measures		✓	✓			0.862	10
CSF# 13	Compliance with safety standards and regulations specified by Saudi Arabian authorities			✓	✓	✓	0.858	7
CSF# 30	Proper handling and storage of modules during transportation and on site				✓	✓	0.858	7
CSF# 8	Adequate funding and financial planning, budget allocation, contingency provisions.	✓		✓	✓		0.855	9
CSF# 7	Compliance with Saudi building codes and regulations	✓	✓	✓	✓	✓	0.851	10
CSF# 3	Skilled and Experienced Labor Force trained in modular housing techniques			✓		✓	0.848	12
CSF# 28	Efficient assembly and installation of modules on site			✓	✓	✓	0.844	13
CSF# 36	Adequate provision for user comfort and convenience, such as HVAC systems and smart home technologies	✓	✓				0.844	13

CSF# 37	Effective collaboration between stakeholders, including designers, builders, and clients	✓	✓	✓	✓	✓	0.834	15
CSF# 27	Timely delivery of modules to site	✓		✓	✓	✓	0.831	16
CSF# 32	Compliance with fire safety regulations			✓		✓	0.824	17
CSF# 35	Proper maintenance and upkeep of modules and building systems	✓	✓				0.824	17
CSF# 22	Optimal energy utilization and conservation efforts.			✓	✓	✓	0.820	19
CSF# 21	Adherence to Saudi Health and Hygiene Standards			✓	✓	✓	0.817	20
CSF# 24	Effective Use of Data Analytics and General Performance Metrics for Modular Housing Projects in Saudi Arabia.	✓	✓				0.817	20
CSF# 26	Effective Supply Chain Management in Modular Housing Factories in Saudi Arabia.			✓	✓	✓	0.813	22
CSF# 29	Adoption of uniform building components and systems.		✓				0.813	22
CSF# 4	Proper factory layout and equipment and Adopting Modern Technologies and Automation	✓	✓	✓			0.810	24
CSF# 15	Availability of reliable suppliers and subcontractors	✓		✓	✓	✓	0.810	24

CSF# 23	Proper training and development of employees	✓	✓	✓	✓	0.810	24	
CSF# 34	Adequate contingency planning and emergency response measures	✓	✓			0.810	24	
CSF# 33	Effective soundproofing and noise reduction measures		✓	✓	✓	0.806	28	
CSF# 19	Effective risk management strategies, identify, assess, and mitigate potential challenges and uncertainties in modular housing projects	✓		✓	✓	0.803	29	
CSF# 38	Use of sustainable and resilient building practices to withstand natural disasters and climate change impacts	✓	✓	✓	✓	0.803	29	
CSF# 5	Efficient Transportation and Logistics, selecting optimal factory and storage locations			✓	✓	✓	0.8	31
CSF# 11	Use of sustainable and environmentally friendly materials		✓	✓		0.796	32	
CSF# 17	Efficient use of space and resources for the functionality of modular housing designs	✓	✓			0.796	32	
CSF# 20	Flexibility in design and customization options	✓	✓			0.796	32	
CSF# 25	Continuous Research and Development to Maintain Competitive Capability in the	✓	✓	✓		0.796	32	

Modular Housing Industry in Saudi Arabia						
CSF# 18	Effective waste management practices, recycling, responsibly disposing of construction waste		✓		✓	0.775 36
CSF# 14	Effective marketing and branding for modular housing projects	✓	✓	✓		0.772 37
CSF# 16	Use of innovative technologies and processes for the Saudi modular housing industry	✓	✓	✓		0.762 38

The planning phase, standing at the inception of the modular housing project lifecycle, is robustly layered with a multitude of CSF's that are intrinsic to setting the project's trajectory towards success. Studies such as those by (Alsehaimi et al., 2009) emphasize the importance of such as 'Adequate Planning and Design' and 'Effective Project Management', embodies the strategic foresight required for preemptively navigating the complexities of the construction process (Wuni et al., 2020b). The focus on aligning with Saudi Arabia's unique regulatory landscape is a testament to the intricate attention to detail that this phase demands. Planning in this context is a dynamic and iterative process, recognizing the need for adaptability and responsiveness to evolving project requirements and external influences. Moreover, 'Skilled and Experienced Labor Force' and 'Adequate funding and financial planning' are recognized as pillars within the planning stage, emphasizing the importance of securing both human and financial capital as precursors to project viability. highlighting that the early-stage amalgamation of skilled expertise and financial rigor is

imperative for mitigating risks and ensuring project fluidity. In essence, the planning phase is a confluence of vision and prudence, setting the foundational parameters within which the modular housing project unfolds (Shibani et al., 2022).

As explained in Table 9, the design phase of modular housing, the confluence of CSF's underlines the complexity and creativity inherent to this stage. It is where aesthetic vision converges with functional pragmatism. Within this phase, considerations such as 'High-quality materials and components', 'Use of sustainable and environmentally friendly materials', and 'Efficient use of space and resources' come to the forefront. These elements highlight the industry's push towards sustainable practices and quality assurance, aligning with global trends and local needs. Moreover, the design phase extends into 'Effective Use of Data Analytics and Performance Metrics', underscoring the need for evidence-based decision-making in design processes. This phase, rich with targeted CSFs, is pivotal in ensuring that the modular units not only meet stringent standards but also embody the innovation and adaptability required in the evolving landscape of Saudi Arabia's housing sector (Schade et al., 2011).

The manufacturing phase in modular housing is important, as it brings the design phase's vision into tangible reality. Here, the focus on 'High-quality materials and components' is paramount, ensuring the durability and resilience of the finished modules. 'Proper factory layout and equipment' along with the 'Adoption of Modern Technologies and Automation' are central to optimizing the production line for efficiency and precision. The integration of 'Effective Supply Chain Management' ensures a streamlined flow of materials, essential for timely project delivery. 'Effective risk management strategies' are also vital

in this phase to preemptively identify and mitigate potential production setbacks. The manufacturing stage, therefore, is a complex interplay of quality control, technological integration, and logistical excellence, all of which are well-documented within the modular housing literature as essential to delivering projects that meet and exceed the industry standards (Zhong et al., 2017).

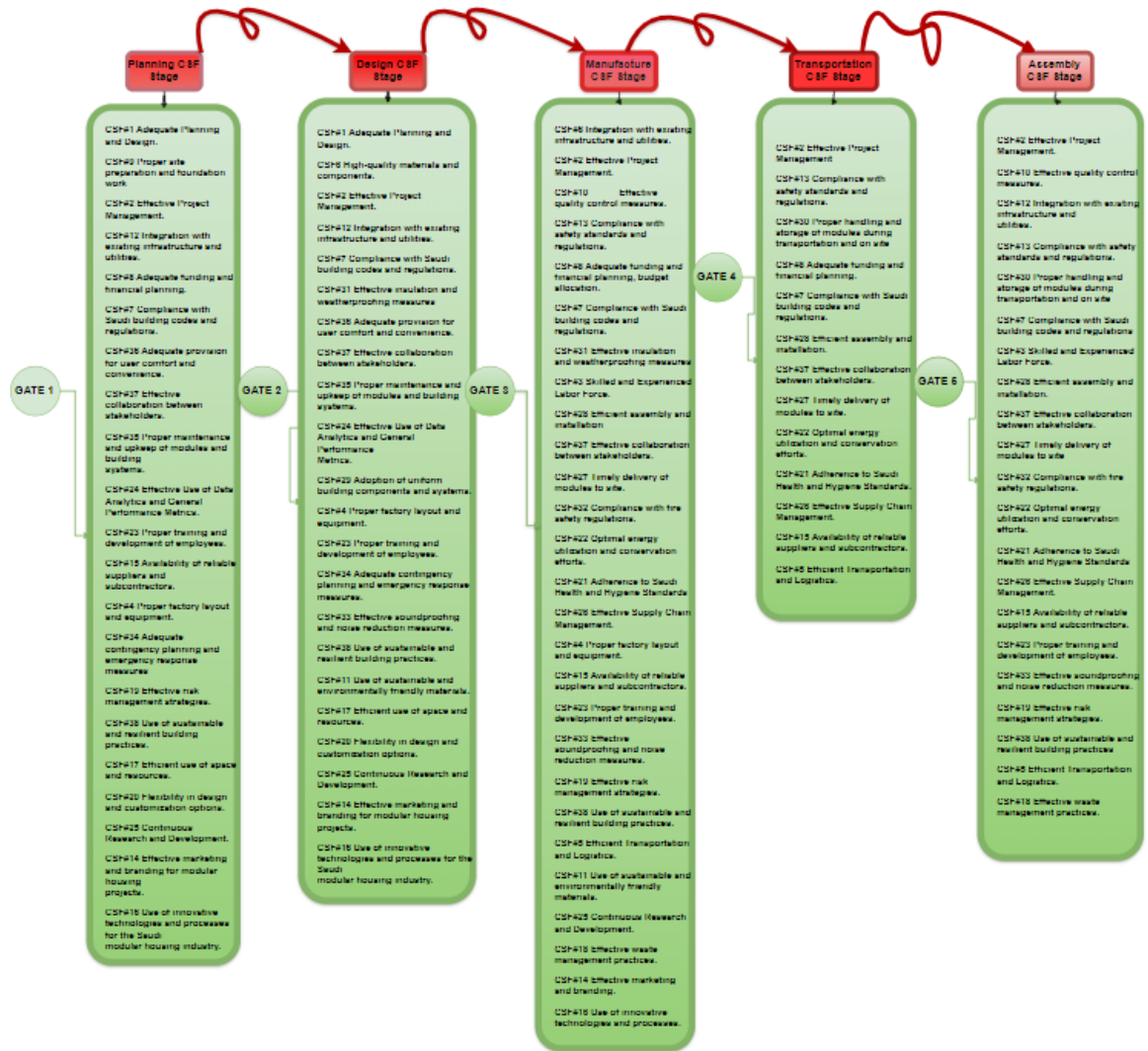


Figure 4.9 A Stage Gate CSF's Framework

The transportation phase in modular housing projects underscores the logistical challenges and strategic considerations of moving modules from factory to site. Central to this phase are 'Efficient Transportation and Logistics' and 'Timely delivery of modules to site,' which emphasize the need for meticulous planning and coordination to ensure the safe and punctual arrival of components. This stage is critical for maintaining project timelines and budgets, reflecting literature that highlights transportation as a key factor in the Modular housing

process. Effective management during this phase ensures the integrity of modules while optimizing cost and time efficiency (Yang et al., 2021). The assembly phase in modular housing projects is critical, marking the culmination of prefabricated modules into a cohesive structure. This stage encompasses factors such as 'Efficient assembly and installation of modules on site' and 'Proper maintenance and upkeep of modules and building systems,' highlighting the precision and care required. It involves complex logistical operations and skilled labor to ensure modules are correctly aligned, secured, and integrated, reflecting the meticulous planning and coordination essential for the success of Modular housing projects (Picard et al., 2022).

4.10 VALIDATION OF THE CSF STAGE GATE MODEL

The Process of validation initially interviewed Directors of the four projects and were asked to rate the importance of each CSF in the framework based on their professional experience and the specific contexts of their projects, also in the process of validation, the director introduce what the most CSFs was essential to achieving success in the project. In some projects, they have not applied some of CSFs in the framework and that lead to some obstacles to achieving success for that project based on the director's feedback. To validate the developed a stage-gate success factors model in modular housing projects within Saudi Arabia, a questionnaire (see **Appendix D**) was designed. This was aimed directly at directors overseeing significant residential projects, capturing insights from four distinct case studies: a residential development in Dammam, a hotel complex on the Red Sea Island, and projects in Mecca and Rabigh. This targeted approach was intended to ensure that the feedback and data collected were directly relevant to high-level project

management and strategic decision-making in major modular housing initiatives. The validation process utilized the feedback from directors of the four projects as method to quantify and analyze the effectiveness of each CSF at various project stages, offering a metric-driven assessment of a stage-gate success factors model applicability. This comprehensive validation effort underscores the critical role of leadership in evaluating and refining project management frameworks. By engaging directly with top-level management, the study ensured that the evaluation of the CSFs was grounded in strategic considerations and practical realities of project execution.

4.10.1 Case Research-1 The Nasaj Town 2 project “Project A”

The Nasaj Town 2 project is in the northern part of Dammam city, within the Al-Wajha suburb. A distinctive feature of the Nasaj Town's location is its proximity to the city's major arterial roads, such as the Riyadh Road. The project encompasses 287 modular housing units, covering a total area of 1,134,000 square meters. It includes all necessary service facilities such as schools, mosques, commercial and social complexes. The project's construction commenced on November 18, 2020, and was completed and delivered in May 2021, taking only 5 months to execute. The construction area of each modular unit is approximately 340 square meters, with each unit consisting of two floors as explained in Figure 7.



Figure 4.10.1 The Nasaj Town 2 project - Project A

Based on the feedback from the director of Project A, the successful implementation and management of CSFs were important in driving the project's success. The director's insights revealed that the tailored application of specific CSFs at various stages of the project lifecycle played a crucial role in achieving the project's objectives. The validation process through director feedback confirmed that the strategic focus on key CSFs was instrumental in managing the complex dynamics of modular housing projects effectively. Emphasizing Adequate Planning and Design (CSF#1), the project was aligned with local environmental conditions and regulatory standards from the outset, enhancing overall project efficiency and compliance. Adequate Funding and Financial Planning (CSF#8) ensured that the project remained financially viable and on budget. Effective Collaboration Between Stakeholders (CSF#37) fostered a cooperative environment, crucial for overcoming challenges during the project. The use of Data Analytics (CSF#24) improved decision-making, leading to more informed strategies and adjustments throughout the project lifecycle.

In the design phase, the focus on uniform building components (CSF#29), flexibility in design (CSF#20), and adherence to building codes (CSF#7) ensured that the project met all technical requirements and customer expectations. During manufacture, prioritizing quality control measures (CSF#10) and skilled labor (CSF#3) maintained high standards of production quality. Efficient Transportation and Logistics (CSF#5) in the transportation phase ensured that all components arrived on time and in perfect condition, crucial for maintaining project timelines and reducing costs associated with delays or damage. The assembly phase benefitted from streamlined processes and risk management strategies that facilitated timely completion and compliance with safety standards. The comparative analysis reveals that Project A aligns more closely with the CSF Stage Gate Model Framework, suggesting that its application of CSFs is robust across all project stages.

4.10.2 Case Research-2 Red Sea Global Shurah Island project “Project B”

Shurah Island, reminiscent of a dolphin in its shape, is situated within the Red Sea destination on the western coast of the Kingdom of Saudi Arabia. It is one of the 92 islands in the archipelago, serving as a habitat for a significant number of unique terrestrial animals and plants explained in Figure 8. Shurah Island is considered the main island of the Red Sea destination, hosting 9 hotels. Each hotel comprises 109 modular housing units in addition to service facilities such as restaurants, fitness centers, sports facilities, and commercial centers. The project's construction commenced on June 2nd, with a scheduled completion date of December 26, 2024. The total construction area on the island is approximately 5.6 square kilometers.



Figure 4.10.2 Red Sea Global Shurah Island project -Project B

According to director of Project B, the validation of CSFs highlights specific factors that led to success across different project stages, as well as some challenges encountered. Success factors in the planning phase included "Adequate Provision for User Comfort and Convenience" (CSF#36), "Proper Factory Layout and Equipment" (CSF#4), and "Use of Innovative Technologies and Processes" (CSF#16), which collectively ensured a strong foundation for the project. These factors contributed to a user-centered design approach, efficient production capabilities, and the incorporation of modern technologies. However, challenges were encountered with "Proper Site Preparation and Foundation Work" (CSF#9) and "Availability of Reliable Suppliers and Subcontractors" (CSF#15), which posed risks to timely project initiation and resource availability.

In the design stage, success was driven by "Adoption of Uniform Building Components and Systems" (CSF#29), "Flexibility in Design and Customization Options" (CSF#20), and

"Compliance with Saudi Building Codes and Regulations" (CSF#7). These factors ensured that the designs were standardized yet adaptable, compliant with local regulations, and could be customized to meet specific needs. The manufacturing stage was notably successful due to the effective implementation of "Proper Factory Layout and Equipment" (CSF#4), ensuring that the production process was optimized for efficiency and quality control. Transportation posed a challenge with "Efficient Transportation and Logistics" (CSF#5), highlighting issues in logistics management. Conversely, "Compliance with Safety Standards and Regulations" (CSF#13) was well-managed, ensuring safe and secure transportation of modules. The assembly stage saw success with "Effective Soundproofing and Noise Reduction Measures" (CSF#33) and "Effective Quality Control Measures" (CSF#10), which were critical in ensuring the final product met quality standards and user expectations. However, the challenge with "Skilled and Experienced Labor Force" (CSF#3) indicated a need for more trained personnel to handle the complex assembly processes. The main challenges faced Project B, logistical and environmental challenges highlighted by the project director. The difficulties in transporting modules from the factory to the island site, coupled with the complexities of preparing foundations on challenging topography, are critical factors that impacted the project's adherence to the framework's CSFs. These challenges underscore the influence of logistical and site-specific factors on the successful implementation of CSFs in modular housing projects. This analysis offers a nuanced understanding of how external variables can significantly impact the efficacy of established frameworks and highlights the need for adaptable approaches that can accommodate unique project constraints.

4.10.3 Case Study-3 AL Baydha Housing Project “Project C”

The AL Baydha Housing Project is one of the developmental housing initiatives affiliated with the Ministry of Housing. The project is in the Bahrah Governorate in the Makkah region, comprising 79 modular housing units. The project began in January 2023 and was delivered in August 2023. For Project C, the director provided insights into the CSFs that contributed to the project's success across different stages, along with the challenges faced.



Figure 4.10.3 AL Baydha Housing Project -Project C

Here's a detailed breakdown Success was largely attributed to "Integration with Existing Infrastructure and Utilities" (CSF#12), "Compliance with Saudi Building Codes and Regulations" (CSF#7), and "Continuous Research and Development to Maintain Competitive Capability in the Modular Housing Industry" (CSF#25). These factors ensured the project was well-integrated with necessary services, compliant with local codes, and at the forefront of industry innovations. However, a challenge was identified in "Proper Training and Development of Employees" (CSF#23), indicating a gap in adequately preparing the workforce for project-specific requirements.

The design stage saw significant contributions from "Proper Maintenance and Upkeep of Modules and Building Systems" (CSF#35) and again, "Integration with Existing Infrastructure and Utilities" (CSF#12), which helped ensure the longevity and functionality of the housing units. The challenge in this phase was "Effective Collaboration Between Stakeholders" (CSF#37), where difficulties in stakeholder coordination may have impacted design decisions and project execution. In manufacturing, "Compliance with Fire Safety Regulations" (CSF#32), "Effective Risk Management Strategies" (CSF#19), and "Use of Sustainable and Resilient Building Practices" (CSF#38) were critical in ensuring safety, managing risks effectively, and incorporating sustainable practices. These elements were vital in maintaining high standards of production and sustainability.

The transportation stage was successfully managed through "Effective Supply Chain Management in Modular Housing Factories" (CSF#26) and "Timely Delivery of Modules to Site" (CSF#27), ensuring efficient logistics and on-time delivery of modules, which are crucial for maintaining project schedules. During assembly, "Availability of Reliable Suppliers and Subcontractors" (CSF#15) and "Adherence to Saudi Health and Hygiene Standards" (CSF#21) were highlighted as key success factors. These ensured that the assembly phase was conducted with high-quality materials and in compliance with health standards, critical for the final construction quality. The director's feedback indicated that while Project C successfully implemented many CSFs leading to notable successes across various phases, there were significant challenges, particularly in training and stakeholder collaboration, which impeded some stages of the project. These challenges underline the necessity for enhanced training programs and better stakeholder management strategies to mitigate issues in future projects.

4.10.4 Case Study-4 The Rabigh Developmental Housing Project “Project D”

The Developmental Housing is one of the initiatives of the Ministry of Housing, aiming to provide residential units for the neediest families within the society, including those under the care of the Ministry of Human Resources and Social Development "Social Security" with a completed application on the "Housing" support portal. The project is located in the Rabigh Governorate in the Makkah region. The project started in January 2020 and was delivered in March 2021, comprising 306 modular housing units.



Figure 4.10.4 The Rabigh Developmental Housing Project-Project D

The director for project D provided insights into the CSFs that contributed to the project's success across different stages, as well as the challenges faced. At planning stage, the use of sustainable and resilient building practices (CSF#38) was pivotal in ensuring the project's readiness to withstand natural disasters and climate change impacts, a critical consideration in the planning stage. However, a significant challenge was noted in maintaining effective maintenance and upkeep of modules (CSF#35), which impacted the project's long-term sustainability and efficiency. During the design stage, compliance with Saudi building codes and regulations (CSF#7), timely delivery of modules to the site (CSF#27), and proper training and development of employees (CSF#23) were key to ensuring the project met all regulatory requirements and was executed on schedule.

However, adequate funding and financial planning (CSF#8) posed a challenge, affecting the overall budget and financial flow of the project.

The manufacture stage did not highlight specific CSFs but continued to deal with the challenges of financial planning. In transportation, optimal energy utilization and conservation efforts (CSF#22) and efficient transportation and logistics (CSF#5) were successful, ensuring energy-efficient and logistically sound module delivery. However, timely delivery of modules (CSF#27) again presented challenges, affecting project timelines and workflow. The assembly phase was effectively managed with the implementation of soundproofing and noise reduction measures (CSF#33) and energy conservation efforts (CSF#22) contributing positively. Nonetheless, challenges included skilled and experienced labor force availability (CSF#3) and effective supply chain management (CSF#26), which hindered the smooth final assembly and completion of the project. The feedback from the director of Project D emphasizes the critical influence of strategic CSFs on the success of the project while also acknowledging the areas of challenge that led to some stages not meeting their full potential. This balanced feedback underscores the necessity for addressing these challenges to enhance future project outcomes in modular housing. The validation of the (CSF) Stage Gate Model Framework through the analysis of case studies Project A, Project B, Project C and Project D concludes that the framework is largely applicable to the modular housing projects within Saudi Arabia.

4.11 PRACTICAL IMPLICATIONS

The Stage-Gate success factors Model is poised to become a crucial and influential framework in modular housing, transforming how buildings are conceptualized, designed,

manufactured, and delivered. As demand for sustainable, cost-effective, and efficient housing solutions increases, this model is gaining significant traction in industry. It provides a structured and systematic method for managing the development process of modular housing projects, incorporating detailed evaluations and approvals at each stage. Featuring key decision points, comprehensive risk assessments, and a focus on continuous improvement, the model enhances the quality, speed, and affordability of projects. It includes gated checkpoints that allow project teams to thoroughly assess feasibility, align objectives, mitigate risks, and make informed decisions. This research explores the significant adoption of the Stage Gate Success Model in modular housing, highlighting its key features, benefits, and profound industry impact. It discusses how the model helps streamline project timelines, fosters collaboration, optimizes resource allocation, and ensures projects meet high quality and customer satisfaction standards. Real-world success stories further validate its indispensability in the modern modular housing landscape.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

This research aimed to devise a comprehensive framework for identifying and validating CSFs essential to the success of modular housing projects in Saudi Arabia. The objective was to create a robust framework that would assist project teams and construction organizations in aligning modular housing projects with the intricacies of the Saudi housing market. This framework was intended to guide the strategic deployment of CSFs through the various stages of project development, from planning and design to assembly and delivery. This study, grounded in a comprehensive analysis of the Saudi Arabian modular housing sector, has provided invaluable insights into the CSFs necessary for the success of modular housing projects. Utilizing a mixed-method research design, the study engaged 58 industry professionals across various cities in Saudi Arabia, ensuring a representative understanding of the sector's dynamics.

The study initially identified 47 CSFs of modular housing from the previous studies after that a pilot study for the factors was conducted with 10 industry modular housing experts in Saudi Arabia aimed to refine and clarify the factors and to know the level of factor contribution with Saudi Arabia modular housing industry the result from the pilot analysis decreases the CSFs from 47 factors to 38 CSFs. The quantitative analysis, central to this research, identified 38 CSFs, each surpassing the critical threshold of importance as

indicated by a mean score above 3.0 on a 5-point Likert scale. This broad spectrum of factors reflects the complex and multifaceted nature of the modular housing industry in Saudi Arabia. Notably, the top five CSFs – Adequate Planning and Design, Effective Project Management, Proper site preparation and foundation work, High-Quality Materials and Components, and Effective quality control measure, and Integration with infrastructure, and compliance with safety, and Proper handling and storage, and Adequate funding planning, and Compliance with SBC (Saudi building code) – emerged as pivotal, with 'Adequate Planning and Design' scoring the highest mean of 4.53. The reliability of the survey instrument was confirmed through a Cronbach's Alpha of 0.982, indicating a high level of internal consistency among the identified CSFs. This robust reliability underscores the validity of the findings and their relevance for strategic planning and policy formulation in the Saudi Arabian modular housing sector.

The CSFs were rigorously characterized and distributed into five distinct phases of project development, with insights derived from interviews with 10 specialists in Saudi Arabia's modular housing industry. This meticulous inquiry refined the understanding of each CSF's role and affirmed their significance across the project stages. The specialists' contributions were instrumental in shaping a stage-gate success factors model, providing a clear pathway for project execution from conception to assembly. This framework was not only validated quantitatively but also enriched with qualitative insights that underscore the interdependencies and the collective impact of these factors on project success. In particular, the planning phase was highlighted as a foundational element, with CSFs such as 'Adequate Planning and Design' receiving the highest prioritization. This phase sets the trajectory for project success, emphasizing the need for thorough initial groundwork and

strategic foresight. The design phase further built on this by focusing on high-quality materials and efficient use of resources, reflecting a strong commitment to sustainability and innovation. From manufacture to assembly, each subsequent phase built upon the preceding ones, with CSFs tailored to address specific needs of each stage. The manufacturing phase emphasized quality control and efficient production processes, while the transportation and assembly phases focused on logistical efficiency and precision in execution, ensuring that the final construction met all specified standards and was delivered on time.

The empirical validation segment detailed the application of the CSF Stage Gate Model across different phases of project execution—Planning, Design, Manufacturing, Transportation, and Assembly. Each project was introduced with its contextual specifics such as scale, location, and key milestones, enhancing the understanding of CSFs in varying environments. The validation process of four projects across the Stage Gate Model Framework and the projects revealed that Project A aligned closely with the framework, suggesting robust application of CSFs across all stages. Projects B and D, while showing alignment in certain phases, indicated potential areas for improvement, particularly in phases where they diverged significantly from the framework's standards. Project C demonstrated competitive alignment, especially in later stages, which highlighted its successful management and operational strategies. The findings underscore the applicability and the need for customization of the CSF Stage Gate Model Framework based on specific project conditions and challenges. The validation of this framework within the Saudi Arabian context confirms its utility in guiding successful modular housing projects, yet also calls for adaptable strategies to accommodate project-specific needs and

environmental conditions. Despite its comprehensive scope, this study acknowledges limitations such as its focus on industry-specific insights, which may not fully encapsulate community-based or environmental considerations. Future research should aim to integrate broader societal impacts and explore the long-term CSF of modular housing projects, and examine the integration of emerging technologies. Additionally, a deeper exploration of the socio-economic implications of modular housing in different regions of Saudi Arabia would be valuable. This research offers a detailed roadmap for enhancing modular housing's efficiency, sustainability, and affordability in Saudi Arabia. These insights will guide policymakers, investors, and industry practitioners in future project planning and execution. Further studies could explore the long-term impacts of these CSFs, delve into the integration of emerging technologies, and assess the socio-economic implications across different Saudi regions. This ongoing research will undoubtedly continue to enrich our understanding and foster more informed decision-making in the sector.

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Appendix A

Refine the CSF'S of modular housing in Saudi Arabia Survey

Invitation to Participate in Master's Research Study:

Dear Participant,

We are pleased to invite you to participate in a significant research study entitled '**A Framework for Implementing Modular Housing Projects in Saudi Arabia.**' This study is conducted by a student pursuing an M.Sc. in Construction Management at King Fahd University of Petroleum and Minerals (KFUPM). The primary aim of this research is to investigate the CSFs of modular housing in the Saudi Arabian context. The goal of this survey is to refine and clarify each success factor of modular housing, exploring their specific contributions to the industry within Saudi Arabia. Your insights and experiences will be invaluable in enhancing our understanding and implementation of modular housing projects. Please be assured that your participation in this survey will remain confidential and the information provided will be used exclusively for academic research purposes. We appreciate your invaluable time and contributions to this important academic endeavor. If you have any questions, or require further information, please do not hesitate to contact email Tarig Arif at g202115490@kfupm.edu.sa or Associate professor Dr. Ahmed Ghaithan at ahmedgh@kfupm.edu.sa .

Thank you for your participation and support.

Yours sincerely,

Tarig Arif Awad Abdellhalim

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Dhahran, 31261, Saudi Arabia

Email *

Valid email

Section 1

Background Information of the Respondent

1. The area or province where you work.*

2. Please provide information about the type of organization you belong to.

(Please choose one)

- ☐ General Contractor
- ☐ Sub/Specialty Contractor
- ☐ Architect
- ☐ Consultant
- ☐ Other (please specify): _____

3. How long have you been employed in the field of engineering/construction?

- ☐ <5 years
 - ☐ 5–10 years
 - ☐ 10–20
 - ☐ >20
 - ☐ Other (please specify): _____
4. How many modular housing projects have you been involved in approximately?
- ☐ <5
 - ☐ 5–10
 - ☐ 10–20
 - ☐ >20
 - ☐ Other (please specify): _____

5. What is your highest academic degree, if any?

END OF SECTION 1

Section 2

Identification and assessment of critical success factors

Kindly evaluate the extent to which each factor contributes to the success of Modular Housing projects in Saudi Arabia. Indicate your assessment using a "Yes" or "No" response. If your answer is "Yes," please rate the factor using the following scale:

- ☐ 1: not important factor,
- ☐ 2 to 4: slightly important factor
- ☐ 5 to 6: important factor
- ☐ 7 to 9: very important factor

☐ 10: most important factor

Category	Critical Success Factor for Modular of housing	Yes/No	Rating
1	Adequate planning and design		
2	Effective project management		
3	Skilled and experienced labor force		
4	Proper factory layout and equipment		
5	Efficient transportation and logistics		
6	High-quality materials and components		
7	Compliance with building codes and regulations		
8	Effective communication between stakeholders		
9	Adequate funding and financial planning		
10	Adequate insurance coverage		
11	Proper site preparation and foundation work		
12	Effective quality control measures		
13	Use of sustainable and environmentally friendly materials		
14	Integration with existing infrastructure and utilities		
15	Compliance with safety standards and regulations		
16	Effective marketing and branding		
17	Adaptability to changing market demands		
18	Availability of reliable suppliers and subcontractors		
19	Use of innovative technologies and processes		
20	Efficient use of space and resources		
21	Effective waste management practices		
22	Effective risk management strategies		
23	Flexibility in design and customization options		
24	Compliance with health and hygiene standards		
25	Availability of warranty and after-sales services		
26	Efficient energy usage and conservation measures		
27	Effective cost management and budgeting		
28	Proper training and development of employees		
29	Effective use of data analytics and performance metrics		
30	Ongoing research and development to stay competitive		
31	Effective supply chain management		
32	Timely delivery of modules to site		
33	Efficient assembly and installation of modules on site		
34	Use of standardized building components and systems		
35	Effective design for transportation and shipping		
36	Proper handling and storage of modules during transportation and on site		
37	Effective insulation and weatherproofing measures		

- 38 Compliance with fire safety regulations
Effective soundproofing and noise reduction
39 measures
Use of advanced building techniques, such as
40 modular framing and penalization
Adequate contingency planning and emergency
41 response measures
Proper maintenance and upkeep of modules and
42 building systems
Adequate provision for user comfort and
convenience, such as HVAC systems and smart
43 home technologies
Effective community engagement and public
44 relations efforts
Effective collaboration between stakeholders,
45 including designers, builders, and clients
Use of sustainable and resilient building practices to
withstand natural disasters and climate change
46 impacts
Adequate training and certification for factory
47 workers and on-site assembly crews
If you have any suggestions or recommendations, please provide them in
the space below:
-

1

END OF SECTION 2

END OF QUESTIONNAIRE

Appendix B

Exploring the Critical Success Factor of modular housing in Saudi Arabia Survey

Invitation to Participate in Master's Research Study:

Dear Participant,

We are pleased to invite you to participate in a significant research study entitled '**A Framework for Implementing Modular Housing Projects in Saudi Arabia.**' This study is conducted by a student pursuing an M.Sc. in Construction Management at King Fahd University of Petroleum and Minerals (KFUPM). The primary aim of this research is to investigate the CSFs of modular housing in the Saudi Arabian context. The goal of this survey is to rank the most success factors of modular housing within the Saudi Arabian context and their contributions in the industry. Your insights and experiences will be invaluable in enhancing our understanding and implementation of modular housing projects. Please be assured that your participation in this survey will remain confidential and the information provided will be used exclusively for academic research purposes. We appreciate your invaluable time and contributions to this important academic endeavor. If you have any questions, or require further information, please do not hesitate to contact email Tarig Arif at g202115490@kfupm.edu.sa or Associate professor Dr. Ahmed Ghaithan at ahmedgh@kfupm.edu.sa .

Thank you for your participation and support.

Yours sincerely,

Tarig Arif Awad Abdellhalim

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Dhahran, 31261, Saudi Arabia

Email*

Email *

Valid email

Section 1

Background Information of the Respondent

1. The area or province where you work.*

2. Please provide information about the type of organization you belong to.

(Please choose one)

- ☐ General Contractor
- ☐ Sub/Specialty Contractor
- ☐ Architect
- ☐ Consultant

☐ Other (please specify): _____

3. How long have you been employed in the field of engineering/construction?

☐ <5 years

☐ 5–10 years

☐ 10–20

☐ >20

☐ Other (please specify): _____

4. How many modular housing projects have you been involved in approximately?

☐ <5

☐ 5–10

☐ 10–20

☐ >20

☐ Other (please specify): _____

5. What is your highest academic degree, if any?

END OF SECTION 1

Section 2

Ranking of the critical success factor of modular housing

The core of this survey involves ranking the critical success factors of modular housing

Saudi Arabia. Your expertise and opinions in this area are highly valued.

Kindly evaluate the extent to which each factor contributes to the success of Modular Housing projects in Saudi Arabia. Please rate the factor using the following scale:

- **1=very insignificant**
- **2=insignificant**
- **3=slightly significant**
- **4=significant**
- **5=very significant**

Sequence	Critical Success Factors of modular housing	Not Effective at all (1)	2	3	4	Very Effective (5)
CSF#1	Adequate Planning and Design to creating modular housing that considers local environmental conditions in saudi					
CSF#2	Effective Project Management , precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape					
CSF#3	Skilled and Experienced Labor Force trained in modular housing techniques					
CSF#4	Proper factory layout and equipment and Adopting Modern Technologies and Automation					
CSF#5	Efficient Transportation and Logistics, selecting optimal factory and storage locations					
CSF#6	High-quality materials and components to guarantee the durability and resilience of modular housing structures.					
CSF#7	Compliance with Saudi building codes and regulations					

CSF#8	Adequate funding and financial planning, budget allocation, contingency provisions.
CSF#9	Proper site preparation and foundation work
CSF#10	Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project.
CSF#11	Use of sustainable and environmentally friendly materials
CSF#12	Integration with existing infrastructure and utilities such as water, electricity, and transportation networks.
CSF#13	Compliance with safety standards and regulations specified by Saudi Arabian authorities
CSF#14	Effective marketing and branding for modular housing projects
CSF#15	Availability of reliable suppliers and subcontractors
CSF#16	Use of innovative technologies and processes for the Saudi modular housing industry
CSF#17	Efficient use of space and resources for the functionality of modular housing designs
CSF#18	Effective waste management practices, recycling, responsibly disposing of construction waste
CSF#19	Effective risk management strategies, identify, assess, and mitigate potential challenges and uncertainties in modular housing projects
CSF#20	Flexibility in design and customization options
CSF#21	Adherence to Saudi Health and Hygiene Standards
CSF#22	Optimal energy utilization and conservation efforts.

CSF#23	Proper training and development of employees
CSF#24	Effective Use of Data Analytics and General Performance Metrics for Modular Housing Projects in Saudi Arabia.
CSF#25	Continuous Research and Development to Maintain Competitive Capability in the Modular Housing Industry in Saudi Arabia
CSF#26	Effective Supply Chain Management in Modular Housing Factories in Saudi Arabia.
CSF#27	Timely delivery of modules to site
CSF#28	Efficient assembly and installation of modules on site
CSF#29	Adoption of uniform building components and systems.
CSF#30	Proper handling and storage of modules during transportation and on site
CSF#31	Effective insulation and weatherproofing measures
CSF#32	Compliance with fire safety regulations
CSF#33	Effective soundproofing and noise reduction measures
CSF#34	Adequate contingency planning and emergency response measures
CSF#35	Proper maintenance and upkeep of modules and building systems
CSF#36	Adequate provision for user comfort and convenience, such as HVAC systems and smart home technologies
CSF#37	Effective collaboration between stakeholders, including designers, builders, and clients
CSF#38	Use of sustainable and resilient building practices to withstand natural disasters and climate change impacts

END OF SECTION 2

END OF QUESTIONNAIRE

Appendix C

Categorize of Critical Success Factors

Invitation to Participate in Master's Research Study:

Dear Participant,

We are pleased to invite you to participate in a significant research study entitled '**A Framework for Implementing Modular Housing Projects in Saudi Arabia.**' This study is conducted by a student pursuing an M.Sc. in Construction Management at King Fahd University of Petroleum and Minerals (KFUPM). The primary aim of this research is to investigate the CSFs of modular housing in the Saudi Arabian context. The goal of this survey is to characterize the success factors of modular housing within the Saudi Arabian context into five stages. Your insights and experiences will be invaluable in enhancing our understanding and implementation of modular housing projects. Please be assured that your participation in this survey will remain confidential and the information provided will be used exclusively for academic research purposes. We appreciate your invaluable time and contributions to this important academic endeavor. If you have any questions, or require further information, please do not hesitate to contact email Tarig Arif at g202115490@kfupm.edu.sa or Associate professor Dr. Ahmed Ghaithan at ahmedgh@kfupm.edu.sa .

Thank you for your participation and support.

Yours sincerely,

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Dhahran, 31261, Saudi Arabia

Email*

Email *

Valid email

Section 1

Background Information of the Respondent

1. The area or province where you work.*

2. Please provide information about the type of organization you belong to.

(Please choose one)

- ☐ General Contractor
 - ☐ Sub/Specialty Contractor
 - ☐ Architect
 - ☐ Consultant
 - ☐ Other (please specify): _____
3. How long have you been employed in the field of engineering/construction?

- ☐ <5 years
- ☐ 5–10 years
- ☐ 10–20
- ☐ >20

- ☐ Other (please specify): _____

4. How many modular housing projects have you been involved in approximately?

- ☐ <5
- ☐ 5–10
- ☐ 10–20
- ☐ >20
- ☐ Other (please specify): _____

5. What is your highest academic degree, if any?

. END OF SECTION 1

Section 2

Dissemination and categorize of Critical Success Factors

you will allocate and classify these Critical success factors into five primary stages: planning, design, manufacturing, transportation, and evaluation. In this section, I will be

seeking your insights regarding which success factors align with each stage to formulate the Stage Gate model framework.

If you notice that certain factors could apply to multiple stages, you have the flexibility to do .

Sequence	Critical Success Factors of modular housing	Planning Stage	Design Stage	Manufacture Stage	Transportation Stage	Assembly Stage
CSF#1	Adequate Planning and Design to creating modular housing that considers local environmental conditions in saudi					
CSF#2	Effective Project Management , precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape					
CSF#3	Skilled and Experienced Labor Force trained in modular housing techniques					
CSF#4	Proper factory layout and equipment and Adopting Modern Technologies and Automation					
CSF#5	Efficient Transportation and Logistics, selecting optimal					

	factory and storage locations
CSF#6	High-quality materials and components to guarantee the durability and resilience of modular housing structures.
CSF#7	Compliance with Saudi building codes and regulations
CSF#8	Adequate funding and financial planning, budget allocation, contingency provisions.
CSF#9	Proper site preparation and foundation work
CSF#10	Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project.
CSF#11	Use of sustainable and environmentally friendly materials
CSF#12	Integration with existing infrastructure and utilities such as water, electricity, and transportation networks.
CSF#13	Compliance with safety standards and regulations

	specified by Saudi Arabian authorities
CSF#14	Effective marketing and branding for modular housing projects
CSF#15	Availability of reliable suppliers and subcontractors
CSF#16	Use of innovative technologies and processes for the saudi modular housing industry
CSF#17	Efficient use of space and resources for the functionality of modular housing designs
CSF#18	Effective waste management practices, recycling, responsibly disposing of construction waste
CSF#19	Effective risk management strategies, identify, assess, and mitigate potential challenges and uncertainties in modular housing projects
CSF#20	Flexibility in design and customization options
CSF#21	Adherence to Saudi Health and Hygiene Standards

CSF#22	Optimal energy utilization and conservation efforts.
CSF#23	Proper training and development of employees
CSF#24	Effective Use of Data Analytics and General Performance Metrics for Modular Housing Projects in Saudi Arabia.
CSF#25	Continuous Research and Development to Maintain Competitive Capability in the Modular Housing Industry in Saudi Arabia
CSF#26	Effective Supply Chain Management in Modular Housing Factories in Saudi Arabia.
CSF#27	Timely delivery of modules to site
CSF#28	Efficient assembly and installation of modules on site
CSF#29	Adoption of uniform building components and systems.
CSF#30	Proper handling and storage of modules during transportation and on site
CSF#31	Effective insulation and

- weatherproofing
measures
- CSF#32 Compliance with
fire safety
regulations
- CSF#33 Effective
soundproofing
and noise
reduction
measures
- CSF#34 Adequate
contingency
planning and
emergency
response
measures
- CSF#35 Proper
maintenance and
upkeep of
modules and
building systems
- CSF#36 Adequate
provision for
user comfort and
convenience,
such as HVAC
systems and
smart home
technologies
- CSF#37 Effective
collaboration
between
stakeholders,
including
designers,
builders, and
clients
- CSF#38 Use of
sustainable and
resilient building
practices to
withstand
natural disasters
and climate
change impacts

. END OF QUESTIONNAIRE

Appendix D

Validate of Critical Success Factors

Invitation to Participate in Master's Research Study:

Dear Participant,

We are pleased to invite you to participate in a significant research study entitled '**A Framework for Implementing Modular Housing Projects in Saudi Arabia.**' This study is conducted by a student pursuing an M.Sc. in Construction Management at King Fahd University of Petroleum and Minerals (KFUPM). The primary aim of this research is to investigate the CSFs of modular housing in the Saudi Arabian context. The goal of this survey is to validate the stage gate framework success factors of modular housing within the Saudi Arabian context. Your insights and experiences will be invaluable in enhancing our understanding and implementation of modular housing projects. Please be assured that your participation in this survey will remain confidential and the information provided will be used exclusively for academic research purposes. We appreciate your invaluable time and contributions to this important academic endeavor. If you have any questions, or require further information, please do not hesitate to contact email Tarig Arif at g202115490@kfupm.edu.sa or Associate professor Dr. Ahmed Ghaithan at ahmedgh@kfupm.edu.sa.

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Dhahran, 31261, Saudi Arabia

Email*

Email *

Valid email

Section 1

Background Information of the Respondent

6. The area or province where you work.*

7. Please provide information about the type of organization you belong to.

(Please choose one)

- ☐ General Contractor
- ☐ Sub/Specialty Contractor
- ☐ Architect
- ☐ Consultant
- ☐ Other (please specify): _____

8. How long have you been employed in the field of engineering/construction?

☐ <5 years

☐ 5–10 years

☐ 10–20

☐ >20

☐ Other (please specify): _____

9. How many modular housing projects have you been involved in approximately?

☐ <5

☐ 5–10

☐ 10–20

☐ >20

☐ Other (please specify): _____

10. What is your highest academic degree, if any?

--

. END OF SECTION 1

Section 2

The core of this survey is to validate the critical success factors of modular housing Saudi

Arabia. In four case residential modular housing project in Saudi Arabia

Your expertise and opinions in this area are highly valued.

Kindly evaluate the extent to which each factor contributes to the success of Modular

Housing projects in Saudi Arabia. Please rate the factor using the

following scale:

- 1=very insignificant
- 2=insignificant
- 3=slightly significant
- 4=significant
- 5=very significant

Project #X						
n	Critical Success Factors of Modular Housing	Planning	Design	Manufacture	Transportation	Assembly
CSF#1	Adequate Planning and Design to creating modular housing that considers local environmental conditions in Saudi					
CSF#9	Proper site preparation and foundation work					
CSF#6	High-quality materials and components to guarantee the durability and resilience of modular housing structures.					
CSF#2	Effective Project Management, precise scheduling, budget management, compliance with Saudi Arabia's regulatory landscape					
CSF#10	Effective quality control measures, modular housing units meet high-quality Saudi standards throughout the project.					

CSF#12	Integration with existing infrastructure and utilities such as water, electricity, and transportation networks.					
CSF#13	Compliance with safety standards and regulations specified by Saudi Arabian authorities					
CSF#30	Proper handling and storage of modules during transportation and on site					
CSF#8	Adequate funding and financial planning, budget allocation, contingency provisions.					
CSF#7	Compliance with Saudi building codes and regulations					
CSF#31	Effective insulation and weatherproofing measures					
CSF#3	Skilled and Experienced Labor Force trained in modular housing techniques					
CSF#36	Adequate provision for user comfort and convenience, such as HVAC systems and smart home technologies					
CSF#28	Efficient assembly and installation of modules on site					
CSF#37	Effective collaboration between stakeholders, including designers, builders, and clients					

CSF#27	Timely delivery of modules to site					
CSF#35	Proper maintenance and upkeep of modules and building systems					
CSF#32	Compliance with fire safety regulations					
CSF#22	Optimal energy utilization and conservation efforts.					
CSF#24	Effective Use of Data Analytics and General Performance Metrics for Modular Housing Projects in Saudi Arabia.					
CSF#21	Adherence to Saudi Health and Hygiene Standards					
CSF#29	Adoption of uniform building components and systems.					
CSF#26	Effective Supply Chain Management in Modular Housing Factories in Saudi Arabia.					
CSF#4	Proper factory layout and equipment and Adopting Modern Technologies and Automation					
CSF#23	Proper training and development of employees					
CSF#34	Adequate contingency planning and emergency response measures					
CSF#15	Availability of reliable suppliers and subcontractors					

CSF#33	Effective soundproofing and noise reduction measures					
CSF#38	Use of sustainable and resilient building practices to withstand natural disasters and climate change impacts					
CSF#19	Effective risk management strategies, identify, assess, and mitigate potential challenges and uncertainties in modular housing projects					
CSF#5	Efficient Transportation and Logistics, selecting optimal factory and storage locations					
CSF#11	Use of sustainable and environmentally friendly materials					
CSF#17	Efficient use of space and resources for the functionality of modular housing designs					
CSF#20	Flexibility in design and customization options					
CSF#25	Continuous Research and Development to Maintain Competitive Capability in the Modular Housing Industry in Saudi Arabia					
CSF#18	Effective waste management practices, recycling, responsibly					

	disposing of construction waste				
CSF#14	Effective marketing and branding for modular housing projects				
CSF#16	Use of innovative technologies and processes for the Saudi modular housing industry				

END OF QUESTIONNAIRE

Vitae

Name :TARIG ARIF AWAD ABDELHALIM

Nationality :SUDANESE

Date of Birth :2/5/1999

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Address :Makkah, Saudi Arabia,

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Academic Background

Master of Science (Construction Engineering and Management), 2024

King Fahad University of Petroleum and Minerals, Saudi Arabia

Bachelor of Science (Civil Engineering), 2021:

Umm Alqura University, Saudi Arabia

Academic Publication: 1- Towards the adoption of modular construction in housing

projects in Saudi Arabia (Under Review)

2- A stage gate model framework of critical success factors of modular
housing in Saudi Arabia (Under Review)

Conference Participation: Presenting a poster at the 7th European International Conference
on Industrial Engineering and Operations Management (IEOM) Conference in
Munich, Germany,2024|