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Critical Success Factors for Residential Building Energy Retrofitting: The Case of Saudi Arabian Residential Buildings Industry

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Abstract: Improving the energy efficiency of residential buildings has become a strategic priority in the Kingdom of Saudi Arabia (KSA), where the housing sector accounts for a significant share of national energy consumption. Retro-fitting existing residential buildings offers a practical, cost-effective pathway to meeting energy conservation targets and advancing the sustainability objectives of Saudi Vision 2030. However, project success depends on the effective identification and management of critical success factors (CSFs) that influence planning and imple-mentation. This study identifies, analyzes, and ranks the key CSFs affecting residential energy retrofits in the Saudi context by integrating academic and industry perspectives. A systematic literature review identified potential CSFs, followed by Social Network Analysis (SNA) to examine their interrelationships and relative importance within scholarly discourse. Subsequently, a structured questionnaire was administered to Saudi industry practitioners to empirically assess the significance of these factors. The findings reveal both alignment and divergence between theoretical and practical perspectives. Design integration, technical expertise, and regulatory compliance emerged as the most influential CSFs, while practitioners placed less emphasis on financial incentives and cultural acceptance. The study provides evidence-based insights to support policymakers and construction professionals in improving residential retrofit practices in Saudi Arabia.

Keywords: Residential buildings; Energy retrofitting; Critical success factors; Social network analysis; Sustainability; Saudi Arabia; Stakeholder perspectives; Building industry.

1. Introduction

The building sector plays a vital role in global energy consumption, contributing to approximately 40% of total energy use and around 36% of global carbon emissions (Adegoke et al., 2024; Obinna Iwuanyanwu et al., 2024). In the Kingdom of Saudi Arabia (KSA), extreme climatic conditions drive high energy demand, particularly for cooling (Adegoke et al., 2024). Elevated ambient temperatures, a heavy reliance on air-conditioning systems, and underperforming building envelopes exacerbate energy demand, especially in regions such as the Eastern Province (Felimban et al., 2019a). Residential buildings in the KSA account for approximately 50% of total electricity consumption (Felimban et al., 2019b), with air conditioning alone responsible for about 70% of electricity usage in the summer (Rababa and Asfour, 2024). This heavy reliance on energy under-scores the urgent need for energy-efficiency improvements in the residential sector. In recognition of these challenges, Vision 2030 outlines ambitious sustainability targets, including improving energy efficiency in the built environment and reducing greenhouse gas emissions (Al-Sinan et al., 2023).

One of the most effective strategies to address this challenge is the retrofitting of existing residential buildings to improve their energy performance (Adegoke et al., 2024). This has been identified as a cost-effective strategy to meet these goals through measures such as enhanced in-sulation, upgraded glazing, improved HVAC performance, and passive design features (Felimban et al., 2023), (Adegoke et al., 2024; Felimban et al., 2019a).

While retrofitting has demonstrated the potential for substantial energy savings, ranging from 25% to 66% depending on the measures implemented (Felimban et al., 2019a), the process in KSA has been slow due to technical, financial, and regulatory barriers. These include the high initial costs of retrofitting, a lack of awareness among building owners, and the limitations of the existing building stock (Obinna Iwuanyanwu et al., 2024; Rababa and Asfour, 2024). Additionally, despite extensive technical and energy-saving studies, a notable gap remains in that contribute to the suc-cess of retrofitting projects in the Saudi residential context. Most work to date focuses on quanti-fying energy savings, simulating retrofit scenarios (Felimban et al., 2023), or defining climate-related constraints for emerging zero-energy homes (Alrashed and Asif, 2015). To overcome these challenges, it is essential to identify the critical success factors (CSFs) for the successful implementation of energy retrofitting projects in the Saudi residential sector.

Previous studies have highlighted several CSFs, including financial incentives, stakeholder engagement, regulatory frameworks, and the selection of appropriate materials and technologies (Adegoke et al., 2024; Obinna Iwuanyanwu et al., 2024). Less well explored are the socio-institutional, financial, regulatory, stakeholder-behavioral, and organizational factors that de-termine whether retrofit interventions are adopted, implemented effectively, and sustained over time in Saudi Arabia. Furthermore, the relationships among CSFs themselves, and how they in-fluence one another, are seldom mapped in the literature, including which are central and which are peripheral. Additionally, the unique climate of Saudi Arabia demands specific retrofitting strate-gies, such as enhancing building facades to reduce heat gain (Rababa and Asfour, 2024). Social Network Analysis (SNA) has been applied in project management to study stakeholder relationships (Eissa et al., 2021), literature review (Salah et al., 2023; Salah and Alabdullatief, 2025), and team communications (Zheng et al., 2016), but not yet, to the author's knowledge, in analyzing the sys-tematic analysis of CSFs for residential energy retrofitting in Saudi Arabia.

1.1 Research aim and objectives

This study aims to explore and synthesize the key success factors in the Saudi Arabian residential building industry. By identifying the key drivers of successful energy retrofitting projects, this research will of informed targeted strategies to accelerate the adoption of energy-efficient retrofitting measures, reduce energy consumption, and support the Kingdom's broader sustainabil-ity goals under Vision 2030. The specific objectives are:

- Extract and synthesize CSFs for residential energy retrofitting from the existing literature.
- Apply SNA to the literature-derived CSFs to map their interrelationships, quantify their influence (e.g., centrality measures), and identify structural positions of factors in the network.
- Collect empirical data via a structured survey of key stakeholders in the Saudi industry to assess which CSFs are prioritized in practice.
- Compare literature-based findings (obtained through the SNA) with empirical survey re-sults to identify alignment, divergence, and context-specific factors, and provide actiona-ble recommendations for policy and practice.

1.2 Research questions

This research is guided by a set of interrelated questions aimed at bridging theoretical insights and practical perspectives on residential building energy retrofitting in Saudi Arabia:

- Which CSFs are most prominently identified in the academic literature on residential building energy retrofitting?
- How are these CSFs structurally interrelated, and which factors demonstrate the highest levels of influence when examined through SNA?
- To what extent do stakeholder perceptions within the Saudi residential sector converge with or diverge from the literature-derived CSFs?
- What additional context-specific CSFs,

if any, emerge from stakeholder insights that are in-sufficiently captured in existing scholarly research, and how do these factors reflect the in-stitutional, climatic, and socio-economic characteristics of the Saudi context?

2. Literature Review

This section reviews the state of knowledge in the field of building energy retrofitting, emphasizing how the literature conceptualizes and categorizes its CSFs and linking them directly to existing scholarly contributions. This background provides the basis for contextualizing the study within the Saudi Arabian residential building industry, ensuring that the subsequent analysis is firmly grounded in both global and local priorities.

2.1 Energy Retrofitting

Energy retrofitting is the process of upgrading existing buildings to improve energy perfor-mance, reduce operational costs, and enhance overall sustainability (Adegoke et al., 2024). Retro-fitting can take different forms, ranging from shallow retrofits, which focus on low-cost measures such as lighting and appliance upgrades, to deep retrofits, which involve comprehensive interven-tions in the building envelope, mechanical systems, and controls to achieve substantial energy savings (Obinna Iwuanyanwu et al., 2024). These strategies are widely applied across various building types, including residential, commercial, and institutional buildings, depending on the scale of intervention and the desired performance outcomes (Citadini De Oliveira et al., 2024). Within this context, the residential building sector represents a key focus area, as housing stock accounts for a significant share of national energy consumption in many countries (He et al., 2021). Among the different retrofit domains, the building envelope is particularly significant, as it serves as the primary barrier regulating heat transfer, air leakage, and daylight penetration (Citadini De Oliveira et al., 2024). Building envelope retrofit strategies have been widely examined in the lit-erature across different climatic contexts, with several studies reporting their potential to improve thermal performance and reduce residential energy demand (Abu Dabous and Hosny, 2025).

Table 1 summarizes the classification of building envelope retrofit strategies, illustrating the variety of measures reported in the literature and their associated energy savings. These strategies include glazing improvements, insulation systems, reflective and cool materials, phase change materials (PCMs), advanced facade systems, and integrated retrofit packages.

Glazing improvements, such as the adoption of double or triple glazing, argon- or kryp-ton-filled windows, and innovative aerogel glazing, are among the most frequently reported strategies, with studies indicating potential energy savings ranging from 13% to 80% (Rakhshan and Friess, 2017). Insulation systems, including reed panels, stone wool, aerogel-based composites, and external insulation finishing systems (EIFS), have been shown to yield savings ranging from 5% to 85%, depending on the building's age, thermal properties, and climate (EVOLA and MARGANI, 2014). Similarly, cool and reflective solutions, such as reflective tiles, cool roof coatings, and light-colored facades, can significantly reduce

Table (1). Classification of Building Envelope Retrofit Strategies and Reported Energy Savings

Retrofit Category	Example Measures	Reported Energy Saving Range	Key References
Glazing Improvements	Double/triple glazing, argon/krypton-filled windows, aerogel glazing	13% – 80%	(Berardi, 2015; Guattari et al., 2015; Rakhshan and Friess, 2017)
Insulation Systems	Wall insulation (reed, stone wool, aerogel, EIFS, composite panels)	5% – 85%	(EVOLA and MARGANI, 2014)
Cool / Reflective Solutions	Cool roofs, reflective tiles, light-colored facades	25% – 98%	(Boarin et al., 2014; Casquero-Modrego and Goñi-Modrego, 2019; Pisello et al., 2015)
PCM-Based Materials	PCM wallboards, PCM plasters, MEEFS with PCM integration	1% – 40%	(Ascione et al., 2015; Marin et al., 2016; Park et al., 2021)
Advanced Facade Systems	Double-skin facade, adaptive solar facade systems (ASTFs)	Qualitative improvements	(Kim et al., 2015; Zhang et al., 2015)
Retrofit Packages	Combined measures: windows, blinds, insulation, lighting, sensors	14% – 50% (deep retrofit up to 50%)	(Cho et al., 2019)

cooling loads, with reported energy savings ranging from 25% to 98% (Boarin et al., 2014; Casquero-Modrego and Goñi-Modrego, 2019; Pisello et al., 2015).

Innovations in PCM-based materials, such as PCM wallboards, plasters, and multifunctional facades with PCM integration, have shown the ability to improve thermal storage and reduce peak demand, with energy savings ranging from 1% to 40% (Ascione et al., 2015; Marin et al., 2016; Park et al., 2021). Advanced facade systems, including double-skin and adaptive solar facades, are also gaining traction. At the same time, their energy savings are often reported qualitatively; they pro-vide substantial benefits in terms of thermal comfort, daylighting, and reduced reliance on mechanical systems (Kim et al., 2015). Finally, retrofit packages that combine multiple strategies, such as upgraded glazing, insulation, lighting controls, and smart sensors, offer integrated solutions capable of achieving energy savings of 14% to 50%. Deep retrofit packages, in particular, can po-tentially achieve up to 50% energy savings (Cho et al., 2019). At the urban scale, residential energy retrofitting is increasingly positioned as a core mechanism to improve the performance of the ex-isting building stock within sustainable urban development frameworks. Such frameworks typically include city-level energy efficiency strategies, low-carbon housing initiatives, and building de-carbonization programs that aim to reduce operational energy demand and emissions without re-lying solely on new construction. In this context, envelope-focused and integrated retrofit strategies directly support these programs by enhancing thermal performance, improving indoor comfort, and delivering measurable energy savings across large segments of the residential sector.

2.2 Critical Success Factors in Building Projects

The success of residential building energy retrofitting projects depends on a range of interrelated factors that span technical, financial, social, and regulatory domains. Previous research has highlighted these factors as CSFs, providing the foundation for a structured evaluation of retrofitting practices worldwide (Adegoke et al., 2024; Adinyira et al., 2012). CSFs refer to the essential elements or conditions that must be met for a project to achieve its intended outcomes, including quality, cost, and time constraints (Al-Otaibi et al., 2025; Citadini De Oliveira et al., 2024). For building projects, including energy retrofitting, these factors are multifaceted, covering technical, economic, environmental, social, and regulatory aspects.

2.2.1 Critical Success Factors

Success factors have long been studied in the project management literature as predictors of overall project performance, particularly in terms of cost, time, and quality outcomes (Adegoke et al., 2024). In the context of building projects, CSFs are defined as factors that influence project success, regardless of the project type, whether it is new construction, renovation, or energy retro-fitting. These factors relate primarily to managerial, organizational, and procedural capabilities that enable effective project delivery (Zahoor and Ali, 2023). The successful execution of projects often depends not only on technical expertise but also on organizational capacity, team communication, and the integration of sustainable practices (Al-Otaibi et al., 2025). Former studies emphasize that early and detailed project planning, coupled with robust scheduling, significantly reduces cost and time overruns (Zahoor and Ali, 2023). Likewise, effective risk management has been identified as a cornerstone of project success, ensuring resilience against uncertainties related to materials, labor, and regulatory requirements (Jia et al., 2021; Ranawaka and Mallawaarachchi, 2018).

Organizational capacity and access to skilled labor are also critical enablers of project success, particularly in rapidly transforming environments such as Saudi Arabia, where workforce dynamics and regulatory reforms directly affect construction performance. In addition, stakeholder communication and collaboration have been repeatedly emphasized as essential for aligning objectives, managing expectations, and minimizing conflicts throughout the project lifecycle (Osei-Kyei and Chan, 2017). Collectively, these general CSFs establish the baseline conditions for effective project execution and give rise to an additional set of factors that are specific to the energy retrofitting context.

2.2.2 Energy-Retrofitting-Specific CSFs

Energy retrofitting projects differ from standard building initiatives due to their focus on in-terventions within existing and often occupied buildings, the need to achieve measurable operational energy performance improvements, and the presence of financial and regulatory constraints specific to retrofit contexts (Park et al., 2021). Consequently, the energy retrofitting literature does not introduce fundamentally new critical success factors; rather, it discusses established CSFs, such as technological readiness, financial viability, stakeholder engagement, and regulatory support, through the lens of these contextual characteristics. For clarity, the following discussion is orga-nized around key thematic dimensions through which the retrofit literature contextualizes these factors.

Technical and climatic context of retrofit interventions

Within the retrofit literature, technological readiness is primarily examined in relation to the compatibility of retrofit interventions with existing building structures, climatic conditions, and occupant behavior. Selecting appropriate measures, such as insulation systems, glazing upgrades, or HVAC retrofits, requires careful consideration of the physical constraints of existing buildings and local climate conditions (Ascione et al., 2015). Adegoke et al. (2024) presented a bibliometric analysis of residential energy retrofitting studies, indicating that technology- and material-related factors are frequently emphasized; however, their effectiveness largely depends on how well they are adapted to local climatic and occupancy patterns. Additionally, the use of advanced tools, in-cluding energy simulation models, intelligent energy management systems, and high-performance envelope solutions, plays a crucial role in planning and evaluating retrofit interventions (Yin et al., 2025). However, the literature consistently highlights that without adequate technical expertise, even mature retrofit technologies may fail to deliver the expected performance outcomes (Mohamed et al., 2023).

Economic and financial considerations:

Financial viability is another dominant theme in energy retrofitting studies, in which CSFs are discussed in the context of long-term investment decisions and uncertainty in economic returns. Lifecycle cost, payback period, return on investment, and access to grants or subsidies are con-sistently identified as key factors influencing the feasibility of retrofit projects (Kim and Medal, 2024). High upfront costs are among the most frequently cited barriers, with financial incentives playing a critical role in mitigating investment risk (Kim and Medal, 2024). In the Saudi Arabian context, low electricity and fuel prices, combined with historically subsidized energy, have further weakened economic incentives for retrofitting (Alyousef and Varnham, 2010). Accordingly, studies suggest that subsidy reform, coupled with targeted financial support mechanisms, can significantly enhance the attractiveness of energy retrofitting initiatives (Alyousef and Varnham, 2010).

Stakeholder awareness and social dimensions

The retrofit literature also places strong emphasis on stakeholder-related factors, particularly awareness, acceptance, and alignment among building owners, occupants, contractors, and poli-cymakers. Awareness of long-term benefits, including energy savings, emissions reduction, and improved indoor comfort, is widely recognized as a prerequisite for successful adoption of retrofits (Alyousef and Varnham, 2010; Stephan and Menassa, 2015). Conversely, limited awareness and misaligned stakeholder priorities, such as tension between short-term cost concerns and long-term environmental performance, are frequently cited as causes of delay or underperformance in retrofit projects (Stephan and Menassa, 2015). Research employing agent-based modeling further indicates that stronger network connectedness among stakeholders enhances value alignment by balancing economic, environmental, and organizational objectives (Stephan and Menassa, 2015).

Regulatory and market environment

Regulatory and institutional conditions form a further contextual lens through which CSFs are discussed in the energy retrofitting literature. Effective regulatory frameworks, building codes, and standards are considered essential enablers of retrofit implementation (Mohamed et al., 2023). In Saudi Arabia, several studies have identified institutional barriers, including insufficiently stringent retrofit-oriented codes, unclear guidelines, and inconsistent enforcement, as significant impediments to large-scale retrofit deployment (Mohamed et al., 2023). In parallel, market-related factors, including access to financial incentives, the availability of certified green materials, and reliable supply chains, are emphasized as mechanisms for reducing the costs and risks associated with retrofit measures (Adegoke et al., 2024).

Beyond regulatory compliance and financial returns, the retrofit literature increasingly highlights the importance of achieving measurable environmental outcomes. Successful retrofit projects are expected to deliver tangible reductions in operational energy demand and greenhouse gas emissions while supporting broader climate resilience goals. Empirical studies of deep-energy retrofits have demonstrated that measures such as solar photovoltaic systems, heat pumps, and enhanced building envelopes can yield substantial reductions in emissions; however, their cost-effectiveness often depends on the presence of supportive incentive schemes (Zhang, 2023). To this end, lifecycle assessment and cost–benefit analyses that incorporate environmental externalities are frequently advocated as decision-support tools to justify and guide more ambitious energy retrofitting strategies (Morano et al., 2024).

2.2.3. CSFs in the Saudi Context

The successful implementation of energy retrofitting projects in Saudi Arabia requires a nu-anced understanding of the country's climatic, economic, institutional, and socio-cultural environment (Al-Tamimi, 2022). Due to extreme heat, high humidity in coastal regions, and frequent dust exposure, building envelopes deteriorate rapidly, making existing building condition and compatibility with retrofit technologies a determining factor (Al-Tamimi, 2022). Felimban et al. (2023) emphasized that roof insulation, wall retrofits, and efficient glazing systems are among the most effective interventions in reducing annual energy consumption in Saudi residential buildings. Umar and Asfour (2025) assessed thermal insulation retrofit strategies to enhance energy efficiency in Saudi Arabia. They concluded that combining roof insulation with HVAC upgrades provides significant energy savings, though challenges such as high costs and regulatory barriers remain. The findings offer practical recommendations, including financial incentives and increased public awareness, to improve energy efficiency in the region. However, the effectiveness of these measures depends on an accurate assessment of the existing envelope and its compatibility with advanced materials and systems.

Equally important are project planning and scheduling, as well as risk management, which are often constrained by limited retrofit experience and fragmented coordination among project participants. Studies by Krarti et al. (2017) suggest that delays in procurement, unclear scope definition, and poor sequencing of retrofit phases can result in performance gaps and cost overruns. Proper planning, supported by risk identification frameworks, is therefore essential to ensure the timely and cost-effective completion of retrofitting projects. The availability of materials and technologies, as well as the quality of design and integration, are also crucial factors in achieving success (Gajić et al., 2021; Piccardo et al., 2020). The local market's limited availability of high-performance insulation materials, efficient glazing, and control systems constrains adoption, particularly in non-urban areas (Al-Tamimi, 2022). Moreover, design integration, ensuring that new systems (HVAC, lighting, renewables) interact effectively with existing structures, directly affects operational performance and user comfort. As demonstrated by Almulhim and Abubakar (2021) Many retrofits underperform due to inadequate coordination between design and execution teams.

From a financial perspective, access to funding, return on investment, economic incentives, and practical financial risk management remain crucial for retrofit success. Although upfront costs are high, several studies (Krarti et al., 2020) confirmed that even moderate retrofit packages yield attractive lifecycle savings, mainly when supported by government subsidies. The High-Efficiency AC Program and the Saudi Energy Efficiency Center (SEEC) initiatives demonstrate the govern-ment's growing focus on de-risking investment through targeted incentives (Krarti et al., 2020). Clear cost–benefit communication and structured financial planning can enhance investor confi-dence and foster stakeholder buy-in.

Adaptation to harsh climatic conditions and commitment to sustainability practices are particularly relevant in the Saudi context (Almulhim and Abubakar, 2021; Krarti et al., 2017). Advanced passive cooling strategies, improved thermal insulation, and the integration of renewable energy systems, particularly solar photovoltaic (PV) systems, have been identified as high-impact measures (Felimban et al., 2023). Furthermore, sustainability-oriented practices, such as lifecycle assessments and energy performance monitoring, are essential to ensure the long-term success of retrofit programs. Communication and coordination among stakeholders, as well as user satisfac-tion, play pivotal roles. Given that retrofitting projects often involve multiple entities, such as owners, consultants, contractors, and regulators, effective communication channels help align project goals and prevent conflicts.

Saudi Arabia's unique cultural context makes cultural acceptance and lifestyle compatibility another critical success factor (Rababa and Asfour, 2024). Despite increasing awareness of sus-tainability, many residents still prioritize traditional architectural forms and high cooling comfort levels (Al-Otaibi et al., 2025; Krarti et al., 2020). Hence, public education and awareness campaigns are crucial for promoting behavioral change and the adoption of energy-saving practices. Institu-tional and policy support remain vital, encompassing regulatory compliance and building codes, government policies and incentives, and institutional capacity.

3. Research Methodology

3.1 Research Design

This study adopted a mixed-methods approach, integrating qualitative and quantitative analyses to identify and evaluate the CSFs influencing residential building energy retrofitting projects in Saudi Arabia. The research process consisted of three main stages:

- A systematic literature review to extract and consolidate potential CSFs from existing academic sources,
- SNA to examine the structural relationships and interdependencies among the identified factors, and
- A stakeholder-based survey to empirically validate and prioritize the CSFs within the Saudi Arabian context.

Figure 1 presents the overall research framework, summarizing the sequence of methodological steps from literature review to empirical validation. The integration of SNA and stakeholder survey ensures both theoretical depth and practical relevance, providing a robust foundation for deriving actionable insights for policymakers and building professionals. This multi-phase design ensured methodological rigor and comprehensive triangulation between theoretical and practical perspec-tives. The SNA and stakeholder survey were conducted as parallel analytical streams to examine CSFs from academic and practitioner perspectives, respectively, with integration achieved through comparative synthesis at the interpretation stage.

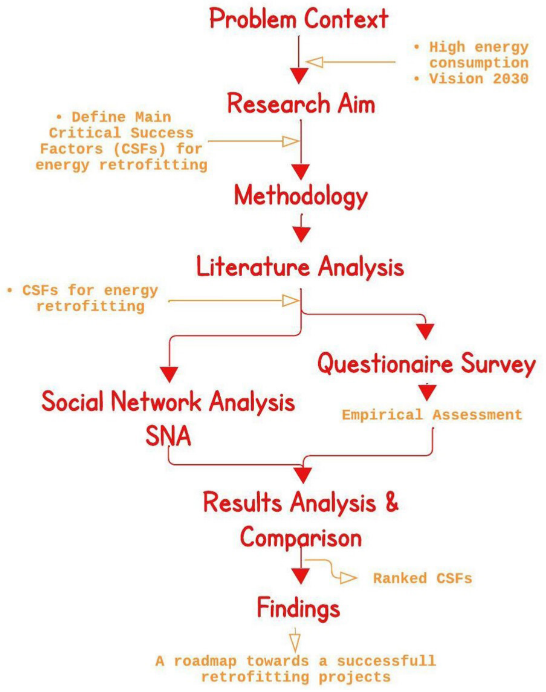


Figure (1). Study Framework

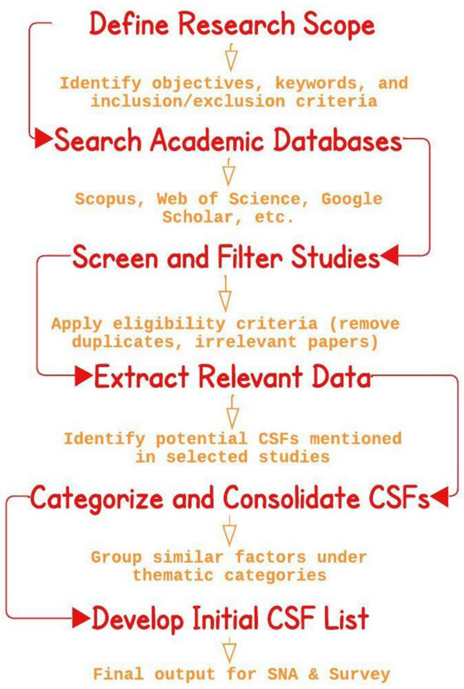


Figure (2). Literature Review to Identify Potential CSFs

Table (2). Mapped CSFs of Retrofitting Projects Against Key References

Code	Factors	References
F1	Existing Building Condition and Compatibility with Technologies	(Ahern and Norton, 2019; Gajić et al., 2021; Matic et al., 2015; Umar and Asfour, 2025)
F2	Project Planning & Scheduling	(Ahmed et al., 2025; Citadini De Oliveira et al., 2024; Dodoo et al., 2010; He et al., 2021; Zhang et al., 2025)
F3	Risk Management	(Anarene et al., 2024; Baset and Jradi, 2024; Jia et al., 2021; McGinley et al., 2025; Ranawaka and Mallawaarachchi, 2018; Seddiki et al., 2021; Zhang et al., 2025)
F4	Material/Technology Availability	(Awoyera et al., 2024; Far and Far, 2019; Kamel and Memari, 2022; Piccardo et al., 2020; Suzi Dilara Mangan and Gül Koçlar Oral, 2014; Umar and Asfour, 2025)
F5	Design & Integration Quality	(Belucio et al., 2021; Darwish et al., 2024; Khabir and Vakilinezhad, 2023; Schütz et al., 2017; Umar and Asfour, 2025; Yin et al., 2025)
F6	Funding Access and Return on Investment (ROI) Considerations.	(Adegoke et al., 2025; Amstalden et al., 2007; Apostolopoulos et al., 2023; Citadini De Oliveira et al., 2024; Gholamzadehmir et al., 2025; He et al., 2019; Neroutsou, 2016; Prabatha et al., 2023; Umar and Asfour, 2025; Zhang, 2023)
F7	Financial Incentives & Subsidies	(Gholamzadehmir et al., 2025; Giandomenico et al., 2022; He et al., 2019; Lang et al., 2025; Prabatha et al., 2023)
F8	Financial Risk Management	(Brown, 2018; Citadini De Oliveira et al., 2024; Prabatha et al., 2023; Stojiljković et al., 2021)
F9	Adaptation to harsh climatic conditions (heat, dust, humidity)	(Citadini De Oliveira et al., 2024; Far and Far, 2019; Kamel and Memari, 2022; Lang et al., 2025; Piccardo et al., 2020; Umar and Asfour, 2025)
F10	Sustainability practices and energy performance upgrades	(Awoyera et al., 2024; Citadini De Oliveira et al., 2024; Kamel and Memari, 2022; Prabatha et al., 2023; Umar and Asfour, 2025; Zhang, 2023)
F11	Communication and coordination among stakeholders	(Bright et al., 2019; Brown, 2018; Citadini De Oliveira et al., 2024; Jadidi et al., 2026)
F12	User satisfaction (Comfort & Indoor Quality)	(Ala-Kotila et al., 2020; Awoyera et al., 2024; Coggins et al., 2022; Faraji et al., 2023; Kamel and Memari, 2022; Yu et al., 2023)
F13	Cultural Acceptance and Lifestyle Compatibility	(Gabriel et al., 2025; He et al., 2019; Torné and Trutnevyte, 2026; Tsang et al., 2022; Yaduvanshi et al., 2025)
F14	Regulatory compliance and building codes	(Ahmed et al., 2025; Citadini De Oliveira et al., 2024; Jadidi et al., 2026; Ozarisoy, 2022; Torné and Trutnevyte, 2026; Umar and Asfour, 2025)
F15	Government Policies & Incentives	(Brown, 2018; Jadidi et al., 2026; Ozarisoy, 2022; Prabatha et al., 2023; Torné and Trutnevyte, 2026)
F16	Contract Clarity & Fairness	(Brown, 2018; Jia et al., 2021; Panakaduwa et al., 2025; Ranawaka and Mallawaarachchi, 2018; Stojiljković et al., 2021)
F17	Technical Expertise	(Jia et al., 2021; Stojiljković et al., 2021; Umar and Asfour, 2025)
F18	Availability and skill level of local labor	(Matic et al., 2015; Shi et al., 2024; Umar and Asfour, 2025; William et al., 2020)
F19	Training & Knowledge Sharing	(Ahmed et al., 2025; Emil and Diab, 2021; Irulegi et al., 2017; Martinopoulos et al., 2018; Umar and Asfour, 2025; Yaduvanshi et al., 2025)
F20	Institutional Capacity	(Bright et al., 2019; Brown, 2018; Jadidi et al., 2026; Ozarisoy and Altan, 2021; Torné and Trutnevyte, 2026)
F21	Smart Technologies & Digitalization	(Awoyera et al., 2024; Citadini De Oliveira et al., 2024; Gonzalez-Caceres et al., 2019; Kamel and Memari, 2022; Lang et al., 2025)
F22	Prefabrication & Modular Systems	(Margani et al., 2020; Matic et al., 2015; Pungercar et al., 2021; Sousa, 2013; Vladimirova and Gong, 2024)

3.2 Literature Review Process

A comprehensive literature review was conducted to identify the CSFs relevant to residential energy retrofitting projects (Figure 2). The search was conducted across major academic databases, including Scopus, Web of Science, and Google Scholar, using keywords such as "energy retrofit," "critical success factors," "building renovation," "sustainability," and "Saudi Arabia."

The inclusion criteria were defined to ensure the quality and relevance of the selected studies. Only peer-reviewed journal articles and conference papers published between 2010 and 2025 were considered. Studies were included if they focused on energy retrofitting, sustainable renovation, or project success factors in the building sector and were published in English. Following the database search, all records were reviewed to remove duplicates and irrelevant publications. A total of 62 studies were retained for in-depth content analysis. Through a systematic review of the literature, 22 common factors were identified as critical to the success of residential energy retrofitting projects in Saudi Arabia (Table 2). Each CSF was assigned a unique identifier (F1–F22) and classified into one of seven dimensions. Table 3 summarizes these factors, along with their corresponding cate-gories and descriptions.

Table (3). Common Factors for Energy Retrofitting in Saudi Residential Buildings

No.	**Factor**	**Description**
Technical & Project-Related		
F1	Existing Building Condition and Compatibility with Technologies	Physical condition, age, and structural integrity of existing residential buildings (villas and apartment units), including deterioration of envelopes and systems, as well as the feasibility of integrating retrofit technologies such as HVAC upgrades, rooftop solar PV, insulation, and smart meters without requiring major structural intervention.
F2	Project Planning & Scheduling	Planning of residential retrofit activities at a small scale, considering household occupancy, phased execution, limited working hours, and minimization of disruption to daily living, with clearly defined scopes, timelines, and milestones tailored to occupied homes.
F3	Risk Management	Identification and mitigation of technical and operational risks specific to residential retrofits, including unforeseen building conditions, occupant-related delays, access limitations, and performance risks associated with retrofitting existing residential systems.
F4	Material/Technology Availability	Availability, affordability, and reliability of retrofit materials and technologies suitable for residential buildings, including insulation systems, glazing, HVAC components, and renewable energy technologies compatible with local residential construction practices.
F5	Design & Integration Quality	Quality of retrofit design solutions that ensure seamless integration of new systems within existing residential layouts, addressing space constraints, architectural compatibility, and ease of installation while maintaining occupant comfort and functionality.
Economic & Financial		
F6	Funding Access and Return on Investment (ROI) Considerations.	Access to financing mechanisms suitable for homeowners, including personal savings, residential loans, and incentive-supported funding, with ROI evaluated at the household level based on affordability, payback period, energy bill savings, and long-term property value enhancement rather than large-scale investment returns.
F7	Financial Incentives & Subsidies	Availability and accessibility of government grants, rebates, tax incentives, and green financing schemes designed to reduce upfront retrofit costs for residential property owners and encourage adoption of energy-efficient measures.
F8	Financial Risk Management	Management of financial risks in residential retrofit projects, including budget overruns, unexpected repair costs, payment delays, contractor cash flow issues, and lifecycle cost considerations from the homeowner's perspective.
Environmental & Sustainability		
F9	Adaptation to harsh climatic conditions (heat, dust, humidity)	Design and implementation of retrofit measures for Saudi Arabia's harsh climate at the residential scale, addressing material durability, system performance, scheduling constraints, and long-term thermal comfort in occupied dwellings.
F10	Sustainability practices and energy performance upgrades	Adoption of energy-efficient, low-impact retrofit solutions in residential buildings, including insulation upgrades, renewable energy systems, and efficient appliances, aims to reduce household energy consumption (kWh/m^2/year), lower emissions, and ensure long-term operability and ease of maintenance.
Social & Stakeholder-Related		
F11	Communication and coordination among stakeholders	Effective coordination among homeowners, small contractors, consultants, and local authorities in residential retrofit projects is especially challenging, as informal management structures and limited technical knowledge among occupants increase the risk of miscommunication and scope changes.
F12	User satisfaction (Comfort & Indoor Quality)	Improvement of occupant comfort and indoor environmental quality, including thermal comfort, lighting, air quality, and noise levels, which directly influence homeowner satisfaction, acceptance of retrofit measures, and sustained energy-saving behavior.
F13	Cultural Acceptance and Lifestyle Compatibility	Alignment of retrofit solutions with household lifestyles, cultural preferences, and daily routines, as well as raising community awareness of retrofit benefits to promote behavioral change and long-term energy-conscious practices in residential settings.

Table (3) Continue. Common Factors for Energy Retrofitting in Saudi Residential Buildings

No.	Factor	Description
Regulatory, Policy & Contractual		
F14	Regulatory compliance and building codes	Compliance of residential retrofit interventions with local and national building regulations, energy codes, and municipal approval requirements applicable to villas and apartment buildings.
F15	Government Policies & Incentives	Policy frameworks and residential-focused programs that support energy retrofitting through mandates, subsidies, or strategic alignment with national sustainability objectives.
F16	Contract Clarity & Fairness	Clear and transparent contractual arrangements in residential retrofit projects, defining scope, responsibilities, payment terms, and dispute resolution mechanisms between homeowners and contractors to reduce conflicts during execution.
Team & Organizational Capacity		
F17	Technical Expertise	Availability of contractors and consultants with specialized knowledge in residential energy retrofitting, including familiarity with existing housing typologies, retrofit technologies, and local climatic conditions.
F18	Availability and skill level of local labor	Saudization policies and shortages affect access to skilled local labor capable of executing residential retrofit work requiring specialized retrofit-related skills.
F19	Training & Knowledge Sharing	Continuous training and dissemination of knowledge among residential retrofit stakeholders to support the effective adoption, operation, and maintenance of new technologies by both professionals and homeowners.
F20	Institutional Capacity	Capacity of relevant institutions and service providers to support, monitor, and manage residential retrofit initiatives, including technical guidance, quality control, and coordination at the neighborhood or community scale.
Technological Advancement		
F21	Smart Technologies & Digitalization	Application of smart and digital technologies in residential retrofits, including IoT devices, smart meters, and simplified BMS solutions to monitor energy use, optimize performance, and analyze occupant behavior using AI/ML-based tools, alongside BIM and simulation for retrofit planning and visualization.
F22	Prefabrication & Modular Systems	Use of off-site-fabricated and modular retrofit components suitable for residential buildings to reduce on-site construction time, minimize disruption to occupants, and improve installation quality.

3.3 Social Network Analysis Procedure

Following factor extraction, SNA was applied to uncover the interconnections among the CSFs and to determine their relative influence within the academic literature (Figure 3). The analysis was performed using Gephi software. Each CSF was represented as a node, while co-occurrence within the same publication represented a link (edge) between nodes (Salah and Alabdullatief, 2025).

Network centrality measures, degree, weighted degree, and betweenness centrality, were computed to evaluate the structural importance of each factor. High-degree nodes indicated frequently cited CSFs, while high-betweenness nodes signified bridging factors connecting distinct thematic clusters. The results from SNA provided a quantitative foundation for identifying the most influential and interdependent success factors, which were subsequently tested through the stake-holder survey. The co-occurrence-based SNA reflects the presence and structural

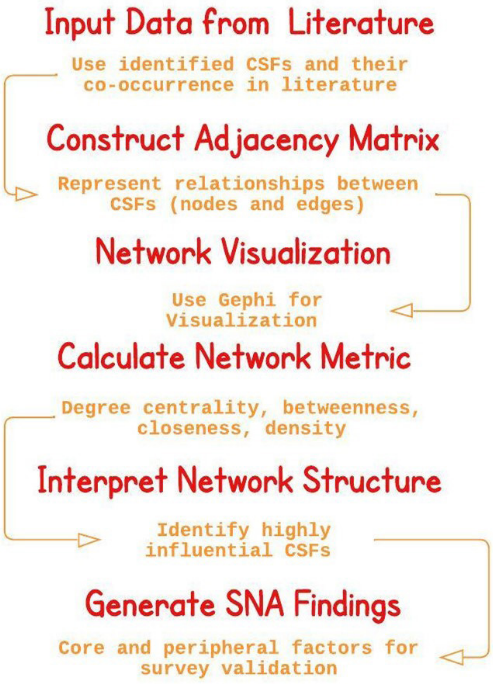


Figure (3). Social Network Analysis Stages

interrelationships of CSFs across the literature, rather than the intensity or depth of their discussion within individual publications; therefore, the results should be interpreted within this analytical scope.

3.4 Questionnaire Analysis

3.4.1 Survey Method

A structured questionnaire was created based on the CSFs identified during the literature review (Figure 4). The survey aimed to measure the perceived importance of each factor using a five-point Likert scale ranging from 1 (“not important”) to 5 (“extremely important”). Participants included architectural and civil engineers, project managers, designers, and policymakers with direct experience or involvement in building retrofit projects across Saudi Arabia. A purposive sampling method was used to ensure variety across professional roles and project types.

The survey was distributed electronically via Google Forms from June to August 2025, yielding 101 valid responses. Demographic data, including years of experience, professional background, and project scale, were collected to provide context for stakeholder perceptions.

3.4.2 Data Analysis

The survey data were analyzed, and descriptive statistics summarized respondent profiles and the mean importance ratings for each CSF. To assess the internal consistency of the questionnaire, Cronbach’s alpha was calculated to ensure the reliability of the measurement scales. Additionally, relative importance indices (RIIs) were computed to rank the CSFs by their practical significance. Furthermore, correlation analysis was conducted to explore relationships among the CSFs, providing insights into potential interdependencies among factors. The comparison of litera-ture-based and stakeholder-based rankings helped identify convergent and divergent factors, highlighting the contextual nuances of energy retrofit implementation in Saudi Arabia.

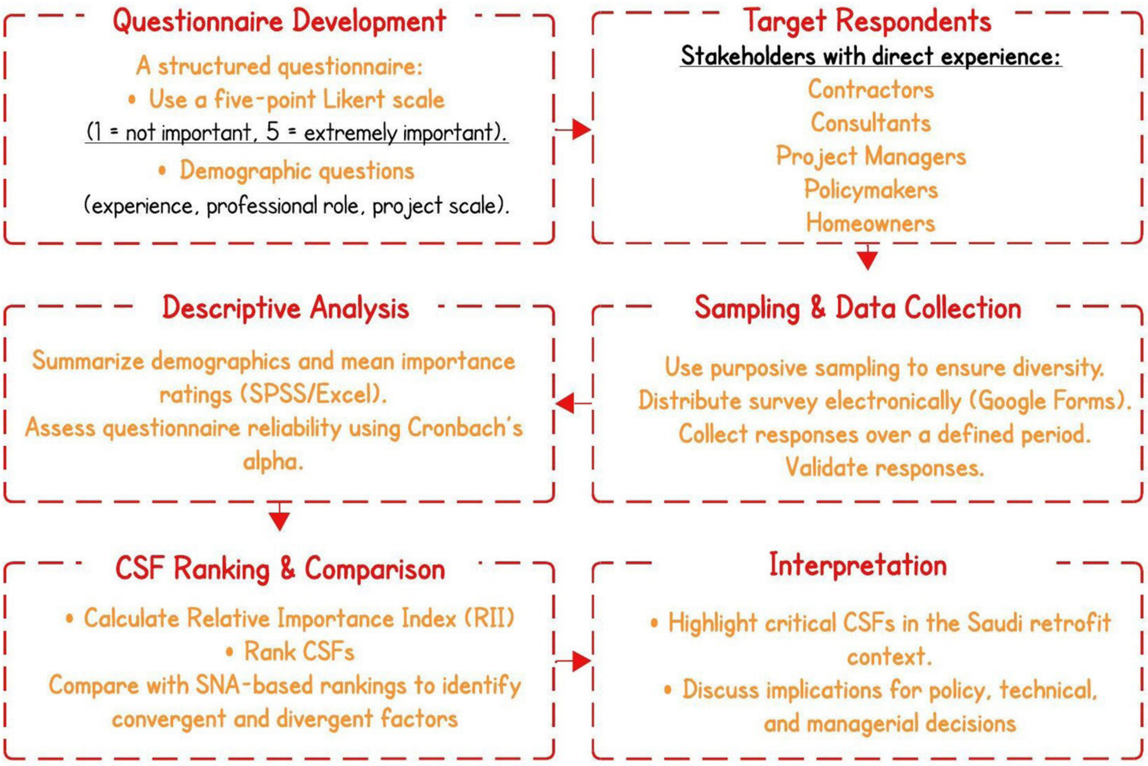


Figure (4). Questionnaire Survey and Results Analysis

4.4. Results

4.1 SNA Network of CSFs

A SNA was conducted to analyze the relationships and relative influence among twenty-two CSFs identified for residential building retrofitting projects in Saudi Arabia. Each node represents a CSF, while edges depict perceived relationships based on the literature review. The aim was to reveal the structural position and influence of each factor within the overall network of success determinants. Network metrics were calculated using Gephi (v0.9.2) for an undirected, weighted network. These metrics included Degree, Weighted Degree, Betweenness Centrality, and Eigen-vector Centrality. Each node indicates a factor, and edges illustrate the strength of relationships based on co-occurrence and thematic links across reviewed studies (Elsayegh and El-adaway, 2021; Salah and Alabdullatief, 2025). The size of each node reflects its weighted degree centrality, indi-cating how connected the factor is to others and its influence within the network.

As illustrated in Figure 5 and Table 4, several CSFs emerged as central nodes, notably Sus-tainability Practices and Energy Performance Upgrades (F10), Funding Access and ROI Consider-ations (F6), Adaptation to Harsh Climatic Conditions (F9), and Regulatory Compliance and Building Codes (F14). These nodes form the structural core of the network, underscoring their strategic importance in ensuring the successful implementation of retrofit within Saudi Arabia's climatic, economic, and policy framework.

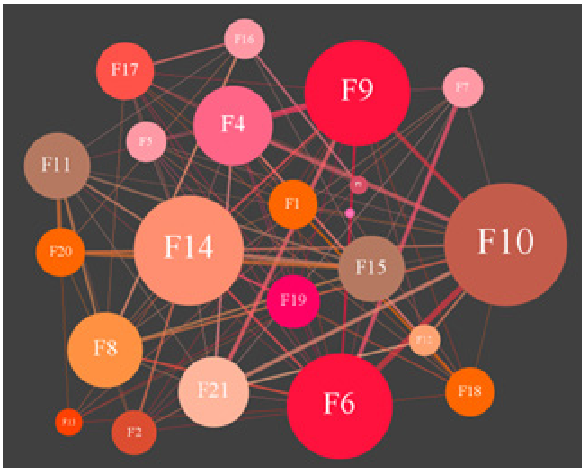


Figure (5). SNA-Network

Factors with high weighted-degree values demonstrate extensive direct interrelations with other CSFs, highlighting their broad and immediate impact on retrofit success (Table 5). Their prominence suggests that financial mechanisms, regulatory frameworks, and technological readiness are among the most significant dimensions influencing project outcomes. High betweenness centrality values identify CSFs that act as structural intermediaries, bridging otherwise discon-nected

Table (4). The Weighted Degrees of CSFs (Direct Influence)

Code	Factor Description	Weighted Degree	Rank
F10	Sustainability Practices and Energy Performance Upgrades	48.0	1
F6	Funding Access and ROI Considerations	42.0	2
F9	Adaptation to Harsh Climatic Conditions	42.0	2
F14	Regulatory Compliance and Building Codes	42.0	2
F4	Material and Technology Availability	31.0	5
F8	Financial Risk Management	29.0	6
F21	Smart Technologies and Digitalization	28.0	7
F11	Communication and Coordination	26.0	8
F15	Government Policies and Incentives	26.0	8
F17	Technical Expertise	25.0	10
F19	Training & Knowledge Sharing	23.0	11
F1	Existing Building Condition and Compatibility	21.0	12
F18	Availability and Skill Level of Local Labor	21.0	12
F2	Project Planning & Scheduling	19.0	14
F20	Institutional Capacity	19.0	14
F5	Design & Integration Quality	18.0	16
F7	Financial Incentives & Subsidies	17.0	17
F16	Contract Clarity & Fairness	15.0	18
F13	Cultural Acceptance and Lifestyle Compatibility	12.0	19
F12	User Satisfaction (Comfort & Indoor Quality)	11.0	20
F3	Risk Management	7.0	21
F22	Prefabrication & Modular Systems	4.0	22

Table (5). The Betweenness Centrality of CSFs (Structural Mediation)

Code	Factor Description	Betweenness Centrality	Rank
F14	Regulatory Compliance and Building Codes	0.09202	1
F10	Sustainability Practices and Energy Performance Upgrades	0.07920	2
F6	Funding Access and ROI Considerations	0.06881	3
F9	Adaptation to Harsh Climatic Conditions	0.06059	4
F17	Technical Expertise	0.05605	5
F8	Financial Risk Management	0.05554	6
F19	Training & Knowledge Sharing	0.05048	7
F4	Material and Technology Availability	0.05068	8
F1	Existing Building Condition and Compatibility	0.04816	9
F18	Availability and Skill Level of Local Labor	0.04816	9
F11	Communication and Coordination	0.04728	11
F12	User Satisfaction (Comfort & Indoor Quality)	0.02230	12
F21	Smart Technologies and Digitalization	0.04685	13
F13	Cultural Acceptance and Lifestyle Compatibility	0.03113	14
F20	Institutional Capacity	0.03178	15
F16	Contract Clarity & Fairness	0.03294	16
F2	Project Planning & Scheduling	0.04333	17
F15	Government Policies and Incentives	0.04389	18
F5	Design & Integration Quality	0.04192	19
F7	Financial Incentives & Subsidies	0.03464	20
F3	Risk Management	0.01955	21
F22	Prefabrication & Modular Systems	0.01500	22

parts of the network. These factors play a vital role in facilitating coordination, knowledge exchange, and integration between technical, institutional, and policy domains.

Analysis of betweenness centrality (Table 5) further shows that factors such as Regulatory Compliance and Building Codes (F14), Sustainability Practices and Energy Performance Upgrades (F10), and Funding Access and ROI Considerations (F6) act as key connectors within the network. These CSFs link otherwise separate areas, supporting coordination, knowledge sharing, and inte-gration across technical, financial, and policy fields. Overall, the network structure underscores the strategic importance of financial mechanisms, regulatory frameworks, sustainability initiatives, and technological readiness in ensuring the successful implementation of energy retrofits. Factors with both high weighted degree and high betweenness centrality form the core of the network, un-derscoring their central role in driving systemic connections and project outcomes.

4.2 Survey Results

4.2.1 Reliability Analysis

To ensure the internal consistency and reliability of the survey instrument, a reliability analysis was conducted on the 22 CSFs. Cronbach's Alpha (α) was calculated for the entire scale based on the (N=101) valid participant responses. The analysis yielded an overall Cronbach's Alpha of α = 0.939. This value is well above the commonly accepted threshold of 0.70 for exploratory research, indi-cating an 'excellent' level of internal consistency (Al-Otaibi et al., 2025). This high degree of re-liability suggests that the 22 items in the questionnaire are cohesive and effectively measure the same underlying construct of CSFs for retrofitting. Therefore, the survey instrument is considered robust and reliable for further statistical analysis.

4.2.2 Respondent Profile

The survey gathered 101 valid responses from participants involved in building retrofitting projects in Saudi Arabia. Respondents represented a variety of professional backgrounds and experience levels. Most participants had more than 5 years of experience, indicating that their responses are based on substantial professional expertise (Table 6). Some reported working in administrative and project-coordination roles related to construction materials and building systems,

Table (6). Experience Distribution

Experience	Count
0–5 years	27
6–10 years	25
11–15 years	17
More than 15 years	32

thereby providing additional operational insights. While respondents had experience with diverse building types, residential buildings were most common, emphasizing the survey's relevance to urban retrofitting projects.

The survey respondents represented diverse professional roles across the building and construction industry, ensuring a comprehensive understanding of retrofit practices from multiple technical and managerial viewpoints. As summarized in Table 7, architects and engineers formed the largest respondent groups, reflecting the technical nature of retrofit projects in Saudi Arabia. The inclusion of project managers, quality specialists, and development professionals adds a managerial dimension, capturing the full lifecycle perspective of retrofit projects. This balance enhances the representativeness of the findings and strengthens the validity of the identified CSFs.

Table (7). Professional Background of Respondents

Profession	Count
Architect	31
Civil/Structural Engineer	29
Project Manager	22
MEP Engineer	8
Quality Control Specialist	6
Development Manager	5
Total	101

Respondents also reported experience across different building categories, indicating a comprehensive understanding of the retrofit landscape. Residential projects were the most commonly represented, followed by commercial and public/non-residential buildings, as shown in Table 8. The prominence of residential experience aligns with Saudi Arabia's ongoing urban renewal and housing modernization initiatives, emphasizing the importance of retrofitting within the residential sector. Meanwhile, participation from commercial, public, and industrial sectors indicates that retrofitting is gaining momentum as a broader sustainability strategy across various building types.

Table (8). Building Type Experience

Building Type	Count
Residential (houses, apartments)	41
Commercial (offices, hotels, factories)	17
Public and non-residential (schools, hospitals)	8
Industrial (warehouses, manufacturing facilities)	7
Historical and traditional	5
Not applicable	23

In addition to evaluating professional backgrounds and project experience, respondents were asked to identify the main technical aspects highlighted in retrofitting projects. The results, sum-marized in Table 9, highlight the most common technical focus areas in the Saudi Arabian retrofit context. The findings indicate that windows and doors, thermal insulation, and renewable energy systems are the most frequently addressed components in retrofitting activities. These focus areas align with the country's national energy-efficiency goals and sustainable building codes, particu-larly those aimed at reducing energy consumption in residential and commercial buildings. The attention to lighting and HVAC systems further reflects a growing awareness of operational energy performance and indoor comfort standards. In contrast, air tightness, though less frequently cited, remains an emerging area of focus, suggesting potential for future technical development and capacity-building initiatives in this domain.

Table (9). Primary Technical Focus Areas in Retrofitting Projects

Technical Aspect	Count
Windows and Doors	23
Insulation	20
Renewable Energy & Solar Systems	20
Lighting	17
HVAC	15
Air Tightness	6

4.2.3 Critical Success Factors (CSFs)

Participants assessed 22 identified CSFs using a five-point Likert scale (1 = not important, 5 = extremely important). Table 10 presents the mean, RII, and ranking of respondents (N) for each factor.

The analysis of the RII indicates that all 22 factors were rated as ranging from moderately to highly important for the success of retrofitting projects in Saudi Arabia. The top-ranked CSFs, Design & Integration Quality (RII = 0.844), Technical Expertise (RII = 0.822), and User Satisfac-tion (RII = 0.808), demonstrate that stakeholders prioritize technical performance, integration ef-ficiency, and occupant comfort. These findings align with the nature of retrofitting projects, which require close coordination between design, execution, and user needs. Most other factors, including Project Planning (F2), Material Availability (F4), and Financial Risk Management (F8), also fall within the "High Importance" category

Table (10). Relative Importance Index (RII) and CSFs Ranking

Code	Critical Success Factor	Mean	RII	Rank
F5	Design & Integration Quality	4.218	0.844	1
F17	Technical Expertise	4.109	0.822	2
F12	User Satisfaction (Comfort & Indoor Quality)	4.040	0.808	3
F14	Regulatory Compliance & Building Codes	3.990	0.798	4
F9	Adaptation to Harsh Climatic Conditions	3.941	0.788	5
F4	Material / Technology Availability	3.941	0.788	5
F15	Governmental Policies & Incentives	3.891	0.778	7
F2	Project Planning & Scheduling	3.881	0.776	8
F1	Existing Building Condition & Compatibility with Technologies	3.871	0.774	9
F8	Financial Risk Management	3.842	0.768	10
F18	Availability & Skill Level of Local Labor	3.842	0.768	11
F10	Sustainability Practices & Energy Performance Upgrades	3.832	0.766	11
F6	Funding Access & ROI Considerations	3.812	0.762	13
F22	Prefabrication & Modular Systems	3.812	0.762	13
F11	Communication & Coordination among Stakeholders	3.762	0.752	15
F3	Risk Management	3.762	0.752	15
F21	Smart Technologies & Digitalization	3.762	0.752	15
F19	Training & Knowledge Sharing	3.752	0.750	18
F20	Institutional Capacity	3.752	0.750	18
F16	Contract Clarity & Fairness	3.743	0.749	20
F13	Cultural Acceptance & Lifestyle Compatibility	3.673	0.735	21
F7	Financial Incentives & Subsidies	3.535	0.707	22

($0.70 \leq \text{RII} < 0.84$). This suggests that respondents consider multiple aspects, including technical, managerial, and policy-related factors, as essential for achieving successful retrofitting outcomes. The lowest RII value was recorded for Financial In-centives & Subsidies (RII = 0.707), suggesting that although economic support mechanisms are acknowledged, they are not regarded as the most critical contributors to project success compared to technical and managerial factors.

4.2.4 Correlation Analysis of Critical Success Factors

To examine the interdependencies among the 22 identified CSFs, a non-parametric Spearman's (ρ) rank correlation was performed using ordinal (Likert) data. The results, presented in Figure 6, revealed predominantly moderate-to-strong positive correlations ($\rho > 0.60$, $p < 0.001$), suggesting that respondents view success factors as complementary rather than competing.

Three major clusters were identified:

- **Technical and Technological Synergy**

Strong correlations were observed between Smart Technologies & Digitalization (F21) and Prefabrication & Modular Systems (F22) ($\rho = 0.677$, $p < 0.001$), highlighting their interde-pendence. Similarly, Design & Integration Quality (F5) was strongly correlated with Sus-tainability Practices (F10) and Material Availability (F4), demonstrating that high-quality design depends on both material readiness and sustainability objectives.

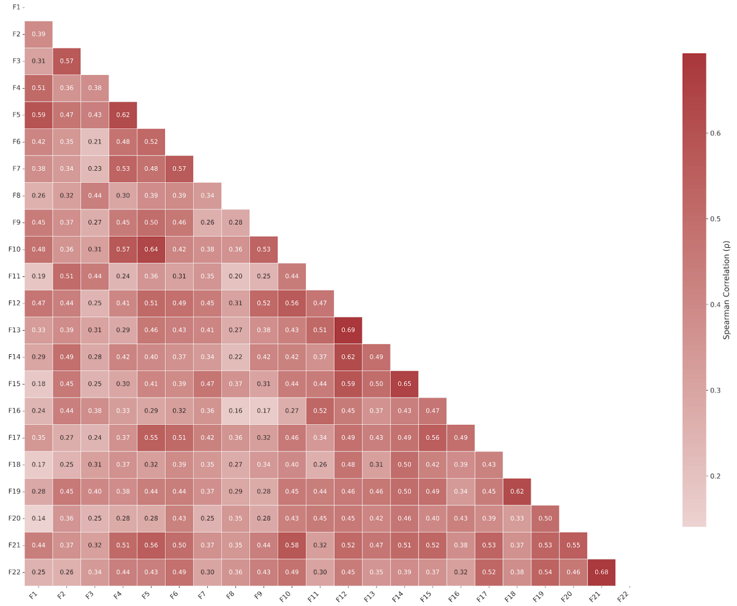
- **Human-Centric and Social Factors**

The strongest overall correlation was between User Satisfaction (F12) and Cultural Ac-ceptance (F13) ($\rho = 0.693$, $p < 0.001$), confirming that retrofit success is socio-technical. Ad-ditionally, Local Labor Availability (F18) and Training & Knowledge Sharing (F19) had a strong association ($\rho = 0.616$, $p < 0.001$), highlighting the important role of skill development in maintaining retrofit capacity.

- **Policy and Governance Framework**

A strong correlation between Regulatory Compliance (F14) and Governmental Policies & Incentives (F15) ($\rho = 0.649$, $p < 0.001$) highlights their interconnected role in governance. A cross-cluster correlation between User Satisfaction (F12) and Regulatory Compliance (F14) ($\rho = 0.621$, $p < 0.001$) indicates that regulatory standards directly enhance user comfort and in-door quality.

Overall, these findings demonstrate that retrofit success depends on an interconnected triad of systems: technical/design, human/social, and policy/governance. Therefore, a comprehensive management approach is essential for achieving sustainable outcomes in retrofitting projects.



	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22
F1																						
F2	0.39																					
F3	0.31	0.57																				
F4	0.51	0.36	0.38																			
F5	0.59	0.47	0.43	0.62																		
F6	0.42	0.35	0.21	0.48	0.52																	
F7	0.38	0.34	0.23	0.53	0.48	0.57																
F8	0.26	0.32	0.44	0.30	0.39	0.39	0.34															
F9	0.45	0.37	0.27	0.45	0.50	0.46	0.26	0.28														
F10	0.48	0.36	0.31	0.57	0.64	0.42	0.38	0.36	0.53													
F11	0.19	0.51	0.44	0.24	0.36	0.31	0.35	0.20	0.25	0.44												
F12	0.47	0.44	0.25	0.41	0.51	0.49	0.45	0.31	0.52	0.56	0.47											
F13	0.33	0.39	0.31	0.29	0.46	0.43	0.41	0.27	0.38	0.43	0.51	0.69										
F14	0.29	0.49	0.28	0.42	0.40	0.37	0.34	0.22	0.42	0.42	0.37	0.62	0.49									
F15	0.18	0.45	0.25	0.30	0.41	0.39	0.47	0.37	0.31	0.44	0.44	0.59	0.50	0.65								
F16	0.24	0.44	0.38	0.33	0.29	0.32	0.36	0.16	0.17	0.27	0.52	0.45	0.37	0.43	0.47							
F17	0.35	0.27	0.24	0.37	0.55	0.51	0.42	0.36	0.32	0.46	0.34	0.49	0.43	0.49	0.56	0.49						
F18	0.17	0.25	0.31	0.37	0.32	0.39	0.35	0.27	0.34	0.40	0.26	0.48	0.31	0.50	0.42	0.39	0.43					
F19	0.28	0.45	0.40	0.38	0.44	0.44	0.37	0.29	0.28	0.45	0.44	0.46	0.46	0.50	0.49	0.34	0.45	0.62				
F20	0.14	0.36	0.25	0.28	0.28	0.43	0.25	0.35	0.28	0.43	0.45	0.45	0.42	0.46	0.40	0.43	0.39	0.33	0.50			
F21	0.44	0.37	0.32	0.51	0.56	0.50	0.37	0.35	0.44	0.58	0.32	0.52	0.47	0.51	0.52	0.38	0.53	0.37	0.53	0.55		
F22	0.25	0.26	0.34	0.44	0.43	0.49	0.30	0.36	0.43	0.49	0.30	0.45	0.35	0.39	0.37	0.32	0.52	0.38	0.54	0.46	0.68	

Figure (6).Spearman Correlation Heatmap or Retrofitting CSFs

4.3 Comparison of Literature vs Survey Results

The comparison between the literature findings and the empirical survey results reveals both agreement and contextual differences in identifying the CSFs influencing retrofitting success in the Saudi Arabian building sector (Table 11). While many of the highly ranked factors align with global research trends, several contextual variations highlight the unique priorities and challenges within Saudi Arabia's construction and retrofitting landscape. From the survey, Design and Integration Quality (F5), Technical Expertise (F17), and User Satisfaction (F12) emerged as the most influen-tial factors. This aligns with previous literature emphasizing the importance of integrated design solutions, multidisciplinary coordination, and the role of skilled professionals in achieving retrofit efficiency and performance. However, User Satisfaction received greater emphasis among Saudi respondents than in international studies, reflecting a growing recognition of occupant comfort and indoor environmental quality as key dimensions of retrofit success.

Table (11). Comparison of CSFs Between Literature and Empirical Findings in the Saudi Context

Critical Success Factor	Evidence from Literature	Survey Results	Saudi Contextual Insights
F5: Design & Integration Quality	A key determinant of retrofit success is through coordination and performance optimization.	Ranked first – most influential factor.	Emphasizes growing focus on integrated design in Saudi retrofitting practice.
F17: Technical Expertise	Essential for planning, energy modeling, and retrofit execution.	Ranked second – strongly supported.	Highlights the need for specialized training and professional capacity building.
F12: User Satisfaction (Comfort & Indoor Quality)	Not consistently prioritized in the literature.	Ranked third – higher emphasis locally.	Indicates growing awareness of occupant well-being and indoor air quality.
F14: Regulatory Compliance & Building Codes	Moderately discussed in global research.	Ranked fourth – highly prioritized.	Reflects the strong influence of new sustainability codes under Vision 2030.
F9: Adaptation to Harsh Climatic Conditions	Rarely emphasized globally except in arid regions.	Ranked fifth – major concern.	Demonstrates Saudi-specific need for climate-resilient retrofitting approaches.
F4: Material & Technology Availability	Commonly identified as a retrofit enabler.	Ranked sixth – consistent with literature.	Highlights supply chain and technology adoption challenges.
F6: Funding Access & ROI	Major determinant of project feasibility.	Ranked 13th – moderately important.	Suggests improving financial support mechanisms and private investment.
F7: Financial Incentives & Subsidies	High priority in European and Asian studies.	Ranked 22nd – lowest emphasis.	Reflects limited awareness or availability of incentive programs.
F13: Cultural Acceptance & Lifestyle Compatibility	Social acceptance is often noted as a soft barrier.	Ranked 21st – low importance.	Indicates a gradual cultural shift toward sustainability in Saudi society.

Furthermore, Regulatory Compliance and Building Codes (F14) and Adaptation to Harsh Climatic Conditions (F9) ranked among the top factors in the survey, indicating a strong contextual influence. These findings highlight the growing impact of Saudi Arabia's vision, which promotes sustainable development, energy efficiency, and stricter environmental regulations. Additionally, the region's extreme climatic conditions require specialized materials and design approaches that are not often prioritized in global literature. This emphasizes the importance of developing region-specific retrofitting standards and technical guidelines tailored to arid climates. In contrast, financial and policy-related factors such as Financial Incentives and Subsidies (F7) and Funding Access and ROI (F6), though frequently discussed in literature, were considered less important by Saudi stakeholders. This may reflect limited awareness of available incentives or recent govern-ment support that has lessened financial constraints. Similarly, Cultural Acceptance and Lifestyle Compatibility (F13) showed a relatively minor influence, suggesting that sustainability-focused retrofitting is gradually gaining social acceptance yet remains an evolving field.

5. Discussions

5.1 Implications for Retrofit Management in the Building Industry

The findings of this study indicate that retrofit success in the Saudi residential sector is pri-marily shaped by factors related to design integration, technical expertise, and user satisfaction (Faraji et al., 2023; Kim and Medal, 2024). These priorities are consistently identified in both the literature-based SNA and the empirical survey, confirming their central role in the effective de-livery of retrofitting (Krarti et al., 2017). However, the survey results place greater emphasis on user satisfaction, suggesting that practitioners increasingly define retrofit success in terms of oc-cupant comfort, usability, and post-occupancy performance, rather than energy savings alone. This shift reflects a move toward user-centered retrofit management, highlighting the importance of integrating technical performance with experiential outcomes. The high importance assigned to these factors suggests that stakeholders view energy retrofitting as a system-level intervention requiring coordinated design and skilled execution, rather than as a series of isolated technical upgrades. The emphasis on user satisfaction further reflects a growing recognition that retrofit performance extends beyond energy savings to include occupant comfort and usability.

Regulatory compliance and adaptation to harsh climatic conditions also emerged as influential factors, particularly in the survey results. While these factors are prevalent in the global literature, their heightened significance in the Saudi context underscores the combined effects of extreme environmental conditions and evolving regulatory frameworks. This finding underscores the need for climate-responsive design strategies and locally tailored retrofit standards, rather than direct adoption of generalized international models. In contrast, financial incentives and return on investment, factors that occupy structurally central positions in the literature-based SNA, were perceived as less critical by Saudi stakeholders. This divergence suggests that institutional conditions, including subsidized energy prices and centralized funding mechanisms, may reduce the perceived influence of financial barriers, thereby shifting managerial attention toward technical readiness and regulatory alignment. Similarly, the relatively low importance assigned to cultural acceptance in-dicates that sustainability-oriented retrofitting is increasingly viewed as compatible with prevailing residential lifestyles, signaling a gradual normalization of such practices (Almulhim and Abubakar, 2021).

Overall, the combined analysis demonstrates that while the literature identifies broadly applicable success factors, their relative importance is reweighted in practice by local climatic, regulatory, and socio-economic conditions. Effective retrofit management in Saudi Arabia, therefore, requires context-sensitive strategies that prioritize professional capacity, integrated design, and climate adaptation, while also recognizing the limitations of transferring retrofit success models across different institutional settings.

5.2 Recommendations for Future Practices and Research Advancements

Building on the empirical findings and contextual insights, this study proposes a framework for future retrofit management and research development in Saudi Arabia. The framework emphasizes four interconnected domains to guide both practitioners and policymakers.

1- Technical and Design Integration

- Develop integrated digital design systems (e.g., BIM-based retrofit modeling) to enhance design coordination and reduce rework.
- Promote research on adaptive design strategies suited to Saudi Arabia's climatic condi-tions.

2- Capacity Building and Professional Development

- Establish specialized training programs, certifications, and university–industry collab-orations to strengthen technical expertise.
- Encourage continuous knowledge sharing through professional networks and retro-fit-focused forums.

3- Regulatory and Policy Enhancement

- Update and enforce building codes to include retrofit-specific guidelines and perfor-mance benchmarks.
- Introduce targeted financial incentives, tax exemptions, and green loan schemes to encourage investment in retrofit projects.

4- User-Centric and Sustainability-Oriented Design

- Priorities occupant comfort, indoor environmental quality, and energy performance as core project outcomes.
- Support innovation in sustainable materials, prefabrication, and smart building systems optimized for the local context.

By implementing these recommendations, Saudi Arabia can strengthen its retrofit management practices and accelerate the transition toward a sustainable, efficient, and climate-resilient built environment. Future research should build on these directions by developing performance assessment models, quantifying the long-term impacts of retrofits, and integrating digital technologies to support data-driven decision-making.

6. Conclusion

This study identified and analyzed the critical success factors (CSFs) influencing retrofitting projects within Saudi Arabia's building industry. The findings reveal that design and integration quality, technical expertise, and user satisfaction are the most significant determinants of retrofit success, emphasizing the importance of coordinated design, professional competence, and occu-pant-centered outcomes. Additionally, regulatory compliance and adaptation to harsh climatic conditions emerged as distinctive priorities, reflecting Saudi Arabia's unique environmental context and the influence of national sustainability initiatives under Vision 2030. From a practical per-spective, these results highlight the need for enhanced design integration, professional training, and more robust policy frameworks that foster sustainable retrofit practices. Industry stakeholders should focus on enhancing technical capacity, adopting digital tools such as BIM, and strengthening collaboration among project participants. Policymakers are encouraged to expand incentive pro-grams and develop retrofit-specific guidelines to accelerate market transformation towards sus-tainability. Academically, this research contributes to the field by contextualizing retrofit success within a developing, climate-sensitive region, thereby bridging global theory with local application. While limited to the Saudi context, the study provides a foundation for future comparative and longitudinal research, including the application of Social Network Analysis (SNA) to explore stakeholder dynamics in delivery. In summary, successful retrofit management in Saudi Arabia depends on integrating technical excellence, regulatory alignment, and user-centered design to achieve energy-efficient, durable, and climate-resilient built environments.

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عوامل النجاح الحاسمة لترميم المباني السكنية من حيث استهلاك الطاقة: دراسة حالة قطاع المباني السكنية في المملكة العربية السعودية

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ملخص البحث. أصبح تحسين كفاءة الطاقة في المباني السكنية أولوية وطنية في المملكة العربية السعودية، حيث يُسهم قطاع الإسكان بشكل كبير في إجمالي استهلاك الطاقة. يُوفر ترميم وتجديد المنازل القائمة نهجاً عملياً وفعّالاً من حيث التكلفة لتحقيق أهداف ترشيد الطاقة ودعم أهداف الاستدامة لرؤية السعودية ٢٠٣٠. ومع ذلك، يعتمد نجاح مشاريع الترميم بشكل كبير على تحديد وإدارة عوامل النجاح الحاسمة التي تؤثر على تخطيطها وتنفيذها. تدرس هذه الدراسة وتصنف عوامل النجاح الحاسمة الرئيسة التي تؤثر على ترميم المباني السكنية لتوفير الطاقة في السياق السعودي، وذلك من خلال الجمع بين الأدلة من الأدبيات الأكاديمية ووجهات نظر أصحاب المصلحة في الصناعة. أُجريت مراجعة منهجية في البداية لتحديد عوامل النجاح الحاسمة المحتملة، والتي حُللت بعد ذلك باستخدام تحليل الشبكات الاجتماعية (SNA) لاستكشاف علاقاتها المتبادلة وأهميتها في المناقشات العلمية. بعد ذلك، أُجري استبيان مُنظم مع الممارسين السعوديين في الصناعة لتقييم الأهمية النسبية لهذه العوامل تجريبياً. تكشف النتائج عن أوجه التشابه والاختلاف بين الرؤى النظرية والآراء العملية. برزت جودة التصميم والتكامل والخبرة الفنية والامتثال التنظيمي بوصفها عوامل نجاح رئيسة، في حين ركز أصحاب المصلحة المحليون بشكل أقل على الحوافز المالية والقبول الثقافي. تقدم الدراسة فهماً شاملاً لنجاح الترميم في المملكة العربية السعودية، وتقدم توصيات قائمة على الأدلة لصانعي السياسات ومحترفي البناء لتحسين تخطيط وإدارة وتنفيذ مشاريع ترميم المساكن لأجل الطاقة.

الكلمات المفتاحية: المباني السكنية، ترميم الطاقة، عوامل النجاح الحاسمة، تحليل الشبكات الاجتماعية، الاستدامة، المملكة العربية السعودية، وجهات نظر أصحاب المصلحة، صناعة البناء.