

## Research Article

# Assessing the Transition toward Industrialized Housing Construction in Jordan

Anas Alkhatatbeh<sup>1,\*</sup> , Layla Sharab<sup>1</sup> , Ahmed Freewan<sup>1</sup> 

<sup>1</sup> Department of Architecture, College of Architecture and Design, Jordan University of Science and Technology, Irbid, 22110, Jordan

\*Corresponding Author: Anas Alkhatatbeh, E-mail: [aaalkhatatbeh17@ad.just.edu.jo](mailto:aaalkhatatbeh17@ad.just.edu.jo)

| Article Info                | Abstract                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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| Article History             | The transition toward industrialized housing construction involves shifting from traditional, craft-based practices to standardized, process-oriented, and technology-driven production systems. This study examines the extent to which such a transition is occurring in Jordan's residential construction sector by assessing the presence of key building industry characteristics and identifying major implementation gaps. A structured questionnaire, based on Lessing's industrialized construction framework, was used to evaluate eight core characteristics: process planning and control, off-site prefabrication, advanced technical systems and automation, information and communication technology (ICT), stakeholder relationships, supply chain integration, customer focus, and performance measurement. Data were collected from 203 construction professionals representing a wide range of residential sector stakeholders. The results indicate a partial and uneven adoption of industrialized construction practices. While planning, basic ICT usage, and performance measurement show moderate levels of implementation, critical features such as off-site prefabrication, automation, standardized systems, and long-term stakeholder collaboration remain weakly developed. Significant variability among firms highlights a fragmented production environment characterized by reactive logistics and limited supply chain integration. Overall, the findings suggest that Jordan's housing sector exhibits a semi-industrialized profile, underscoring the need for coordinated policy support, capacity building, and enhanced stakeholder collaboration to advance industrialized housing construction. |
| Received Sep 10, 2025       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Revised Jan 19, 2026        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Accepted Feb 12, 2026       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
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## 1. Introduction

The industrialization of construction represents a fundamental shift from traditional, craft-based building methods toward highly structured, standardized, and technology-driven production systems. The United Nations Economic Commission defines housing industrialization as a comprehensive process characterized by production continuity, standardization, mechanization, highly organized engineering, integration across production stages, and coordinated research and development activities [1]. In this context, the “building industry” extends beyond physical construction activities to encompass the effective

management, preparation, and control of resources, processes, and outputs, supported by advanced building components and systems [2].

Globally, industrialized construction emerged as a response to severe housing shortages following World War II. Many countries faced extraordinary demand for rapid housing delivery, which accelerated the adoption of prefabrication and system-building approaches. These developments marked a transition toward off-site construction, standardized components, and more efficient production systems [3]. As housing prices and production costs continued to rise, the home-building sector became a focal point for innovation, with industrialized building promoted as a viable solution capable of addressing both large-scale housing demand and economic pressures [2].

Initially, industrialized construction was understood primarily as the application of mass-production principles to building, emphasizing large production series, technological standardization, limited variation, and strict coordination of tasks and labor [3]. Over time, this narrow interpretation evolved into a more comprehensive framework. The term now involves advanced process planning and control, off-site manufacturing of building components, long-term collaborative relationships among stakeholders, integrated supply chain management, customer-focused design, extensive use of information and communication technology (ICT), and systematic performance measurement with continuous learning and feedback [4].

Although recent studies have begun to examine the challenges associated with the adoption of industrialized construction in the Middle East, research focusing specifically on Jordan remains limited and predominantly descriptive rather than analytical. Existing Jordanian literature generally identifies broad barriers such as low levels of digital readiness, weak supply chain integration, and limited adoption of prefabrication without providing a structured or comprehensive evaluation of industrialized construction practices. This lack of a systematic analytical framework results in a significant knowledge gap regarding the current state of industrialization in Jordan, including which practices are partially implemented, which remain underdeveloped or absent, and where the most critical systemic weaknesses exist. Addressing this gap, the present study offers the first methodical assessment of industrialized construction in Jordan by contextualizing internationally recognized industrialization principles within the local Jordanian construction context. In doing so, the study establishes a much-needed baseline to support future research, inform policy development, and enable industry benchmarking, thereby contributing both empirical

evidence and strategic insights toward advancing the adoption of industrialized construction in Jordan.

## **2. Literature Review**

### **2.1. Core Principles of Industrialized Construction**

Prefabrication is widely recognized as a central component of industrialized construction. Defined as the production of building components in controlled off-site environments, prefabrication offers improved quality control, reduced construction time, and lower environmental impacts. However, its effective implementation requires rigorous early-stage design coordination, restructured traditional supply chains, and precise logistical planning to ensure compatibility between off-site production and on-site assembly [5-7].

Standardization is another fundamental pillar of industrialized construction, promoting uniformity in building components, interfaces, and processes to enhance interchangeability and assembly efficiency. As discussed by Gibb, standardization reduces on-site variability and facilitates integration across construction activities [8]. Standardization strategies may range from flexible component-based systems to more rigid complete-system approaches, and they also support regulatory approval processes by enabling consistent evaluation of well-documented building solutions [3].

### **2.2. Role of ICT, Lean, and Agile Approaches**

Information and Communication Technology (ICT) is a key enabler of industrialized construction. Lessing, et al. [3]. highlighted the importance of digital tools such as Building Information Modeling (BIM), computer-aided design (CAD), and Enterprise Resource Planning (ERP) systems in supporting design coordination, production planning, and supply chain communication [3]. These technologies enable product customization within standardized systems while improving design accuracy, reducing errors, and enhancing coordination among stakeholders. BIM, in particular, allows stakeholders to visualize, simulate, and coordinate building processes prior to physical construction, improving integration and reducing rework [3].

Lean and agile construction paradigms further support the objectives of industrialized construction. Lean construction emphasizes waste reduction, process optimization, and continuous improvement, making it particularly suitable for off-site manufacturing and on-site assembly environments [9, 10]. Agile construction focuses on flexibility, collaboration, and responsiveness to change, which is valuable in

projects requiring customization or adaptation to evolving client requirements [11]. Together, these approaches align with the efficiency, adaptability, and customer focus central to industrialized construction.

### 2.3. Supply Chain Management in Industrialized Construction

Effective supply chain management (SCM) is critical to the success of industrialized construction. Vrijhoef and Koskela identified four primary roles of SCM: improving site interfaces, enhancing internal supply chain efficiency, shifting construction activities off-site, and integrating supply chains with on-site operations. These strategies aim to reduce waste, streamline workflows, and promote early stakeholder involvement. In industrialized construction, SCM often relies on long-term supplier partnerships, logistics planning, and early design integration to ensure coordination across production and construction phases [7].

### 2.4. International Studies on Industrialized Housing

Several studies have examined industrialized housing from technological, organizational, and economic perspectives. Lessing and Brege defined the housing industry as a system of production, information, and management processes that treat housing as a product delivered through a production line, emphasizing innovation, change, and customer satisfaction [2, 12]. Mostafa et al. argued that prefabricated housing methods enhance quality, cost efficiency, and construction speed, recommending prefabrication for organizations seeking responsive and efficient housing delivery strategies [13].

Hwang et al. evaluated industrialized housing systems with a focus on affordability and found that semi-industrialized precast concrete systems offered a cost-effective solution for large-scale housing development [14]. Chauhan et al. and Hwang et al. demonstrated that combining prefabrication with advanced planning methods accelerates project completion and improves performance [14, 15]. Rahman and Sobuz compared individual panel systems (IPS) with prefabricated volumetric construction (PPVC) and found that volumetric systems significantly reduced construction time, cost, waste, and site disturbances while improving workmanship quality [16].

Other studies addressed system selection and performance drivers. Hanafi et al. examined the use of steel concrete formwork systems in Malaysia and identified project scale and company capital as key selection factors [17]. Mostafa et al. introduced four strategies and used simulation to balance the trade-offs between housing supply and demand in Australia. They assessed house completion time, cost, and

customer preferences as key factors, concluding that different building strategies could bridge the gap between demand and supply while affecting project completion time and cost [18]. In another study, Mostafa et al. explored multiple housing production strategies, built-to-stock (BTS), assemble-to-order (ATO), design-to-order (DTO), and self-building house (SBH), and concluded that off-site manufacturing offered the most effective balance between cost, time, and customer preference [13]. Bowles et al. emphasized the importance of affordability and highlighted the complexity of housing production, which encompasses organizational, technological, and creative dimensions [19]. Adenuga focused on quality assurance practices, identifying communication and implementation gaps as major obstacles to achieving quality outcomes in construction projects [20]. Rocha et al. investigated product modularity and demonstrated its positive influence on quality and production efficiency through comparative studies in Brazil and the UK [21].

## 2.5. Industrialized Construction in Jordan and the MENA Region

Recent literature indicates that industrialized construction remains underdeveloped across much of the MENA region. Studies from Jordan report that off-site prefabrication, automation, and advanced manufacturing are largely absent from mainstream practice, with construction characterized by fragmented workflows, minimal standardization, and limited ICT integration [22-24]. Similar challenges are reported in Libya and Egypt, where transportation constraints, weak logistical coordination, and regulatory barriers hinder the implementation of modular construction systems [22, 25]. These findings suggest that the limited adoption of industrialized construction in the region reflects systemic structural challenges rather than isolated national conditions.

At the organizational and cultural level, several studies identify knowledge gaps and a strong preference for traditional construction methods as major barriers to industrialization. Resistance to change, combined with limited familiarity with prefabricated and modular systems, constrains adoption among both practitioners and clients. These challenges are compounded by economic and regulatory constraints, including high initial investment costs, weak policy frameworks, and a lack of financial incentives, all of which discourage private-sector investment in industrialized construction methods [22, 26]. Nevertheless, research highlights opportunities for advancement through policy reform, government-led initiatives, and improved stakeholder collaboration[26].

Recent research examining lean construction adoption in Jordan indicates that the philosophy remains insufficiently understood and formally practiced within the industry, despite its demonstrated effectiveness internationally. Using Jordan as a case study and drawing on perceptions from contractors, consultants, and owners, the study found strong consensus among stakeholder groups regarding the principal barriers to lean adoption. The most critical challenges include limited support from top management, insufficient training of the workforce, low awareness and understanding of lean principles, inadequate information management to support learning and corrective actions, and weak stakeholder involvement and transparency. To address these issues, the literature emphasizes the need for leadership-driven change within construction firms, greater institutional support from government and academic bodies through education and training programs, and enhanced collaboration and trust among project stakeholders [23]. These findings underscore the close interrelationship between process maturity, collaboration, and the feasibility of industrialized construction.

Fragmented supply chains and process inefficiencies are identified as major barriers to industrialized construction across the region. In Jordan, short-term procurement practices and limited supplier collaboration result in coordination gaps, delays, and inconsistent quality, undermining standardization and just-in-time delivery systems. Similar challenges are documented in Egypt, where misalignment between manufacturing and on-site assembly further restricts modular construction implementation [25]. A broader regional logistics study identified 23 distinct challenges affecting construction supply chains, including poor material handling and storage, inefficient scheduling and lack of real-time tracking. The study emphasized lean construction practices, ICT-based logistics tools, and collaborative partnerships as critical success factors for addressing these inefficiencies [27].

Against this backdrop, digitalization and Construction 4.0 technologies, including BIM, digital collaboration platforms, automation, and robotics, are increasingly shaping global construction practices. However, research from Jordan indicates that digital adoption remains at an early stage due to shortages of skilled personnel, high ICT costs, and limited private-sector investment in research and development [28]. Despite these barriers, studies reveal a high willingness among Jordanian professionals, particularly younger engineers and larger firms, to adopt technologies such as BIM, drones, 3D printing, and advanced modeling tools. This suggests that the main gap is not demand but readiness, practitioners are willing to embrace digital and automated solutions if given the training, resources, and supportive infrastructure [28]

Among digital technologies, BIM represents one of the more widely adopted digital technologies in Jordan, with surveys indicating that over 60% of respondents report some level of BIM use in construction supply chain management [29], while the gradual uptake of project management and communication platforms further suggests incremental progress toward digital integration [28]. To accelerate ICT and automation adoption, the literature emphasizes the importance of capacity building through targeted training programs and higher education curricula aimed at producing digitally skilled construction professionals. Financial and institutional support, such as subsidizing initial technology costs and mandating BIM use in public projects, has also been identified as critical to overcoming adoption inertia [28]. For example, some Gulf countries have launched initiatives around Construction 4.0 (Dubai's 3D Printing Strategy and Saudi Arabia's NEOM smart city investments are often noted, though primarily in industry reports). Additionally, researchers emphasize improving the digital infrastructure and standards, e.g. developing interoperability standards, data exchange protocols, and robust internet connectivity on job sites. These would facilitate smoother implementation of ICT tools across supply chains. Lastly, the high willingness of young professionals to use technologies like drones and 3D printers suggests that pilot projects and success stories could have a demonstration effect. By publicizing local case studies where digital methods saved time or cost, the industry can build confidence in these approaches [28].

Regional success stories demonstrate the potential of industrialized construction. Saudi Arabia's promotion of Modern Methods of Construction under Vision 2030 illustrates the economic and environmental benefits achievable through large-scale modular adoption, including GDP growth, employment generation and reducing construction waste and carbon emissions [30]. In parallel, emerging frameworks from Egypt and other countries propose context-specific roadmaps for integrating off-site construction into local housing programs, identifying critical success factors and mitigation strategies applicable to similar regional contexts. The framework identifies context-specific barriers and critical success factors (e.g. community acceptance, supply chain readiness) and suggests mitigation strategies. Recommendations include providing incentives to offset high initial costs, improving supply chain integration, and strengthening training for the workforce. Such research offers a roadmap for other MENA countries to adapt global prefabricated practices to local needs [25, 31].

Collectively, the literature suggests that while interest in industrialized construction is growing across the MENA region, its widespread implementation remains constrained by interconnected process,

technological, and supply chain limitations. Without substantial improvements in logistics coordination, digital integration, and organizational readiness, efforts to adopt advanced construction technologies are likely to remain fragmented. At the same time, the convergence of policy support, technological willingness, and emerging regional frameworks presents a significant opportunity to advance industrialized housing practices. These findings highlight the need for empirical assessments that evaluate the actual level of industrialized construction adoption at the firm level and examine how organizational, technological, and supply chain factors interact in practice, an evidence gap that the present study seeks to address [27].

### 3. Materials and Methods

#### 3.1. Research Design and Data Collection

This study employs a survey research design to evaluate the level of industrialization in Jordan's construction sector especially housing projects. The survey was developed based on Lessing [32] framework, which conceptualizes industrialized construction through eight characteristics. Unlike studies that focus narrowly on prefabrication or manufacturing techniques, Lessing's framework provide a holistic perspective by addressing organizational, technological, logistical and customer-oriented dimensions of industrialization. Furthermore, the framework was developed through extensive empirical research, including expert interviews, case studies, and validation workshops, which enhances its credibility and suitability for application in different national contexts.

Accordingly, the survey consisted of 61 items, grouped into eight sections, each corresponding to one of Lessing's industrialization characteristics. All items were measured using a five-point Likert scale. Prior to large-scale distribution, a pilot study was conducted to assess the clarity, relevance and comprehensiveness of the questionnaire. Feedback was obtained from five experts from both academia and industry. Based on their comments, minor revisions were made to improve question wording and ensure contextual relevance to the Jordanian construction sector.

The finalized questionnaire was translated into Arabic to ensure clarity for respondents. Data collection was conducted between January 2025 and March 2025. The survey was distributed using email invitations, and LinkedIn accounts, and was administered online using Google Forms. A purposive sampling strategy was adopted to target professionals with relevant experience in the Jordanian housing construction sector, including representatives from housing developers, contracting firms, consulting

companies, material producers, and building element manufacturers. All respondents were operating within Jordan and reported professional experience ranging from seven to over twenty years, ensuring informed and reliable responses. A total of 203 valid responses were collected out of 300. The respondents comprised 78 contractors and housing companies (37.50%), 68 Consultants (32.50%), 31 Academics (17.50%), and 26 other nature of business (12.50%).

According to Figure 1, the survey assessed the following eight characteristics of industrialized building practices, as defined by Lessing [32], which represents the research stages:

- A. Planning and control of processes: This dimension examines the extent to which construction activities are guided by structured planning and process control mechanisms. The average mean score reflects the degree of adherence to efficient and systematic planning procedures among construction firms in Jordan.
- B. Use of prefabricated elements off-site: This characteristic evaluates the prevalence of centralized production facilities for readymade components and the minimization of on-site assembly and finishing. The mean score indicates the extent to which prefabrication practices are adopted within the industry.
- C. Advanced technical systems and automation: This component assesses the integration of modern technical systems and automation technologies in construction operations. The average score serves as a measure of technological advancement and automation within Jordanian construction practices.
- D. Application of information and communication technology (ICT): This characteristic measures the implementation of ICT tools to support construction processes. The average score indicates how extensively such digital technologies are utilized by companies in Jordan.
- E. Long-term relationships among stakeholders: This aspect explores the presence and strength of sustained collaborations among various participants in the construction process. The mean score reflects the level of relationship-building and cooperative engagement within the sector.
- F. Integration of supply chain management: This characteristic evaluates how effectively supply chain management practices are incorporated into construction workflows. The corresponding average score serves as an indicator of logistical efficiency and coordination within the industry.
- G. Customer focus: This dimension assesses the priority placed on client satisfaction and responsiveness to customer needs in construction projects. The mean score reveals the degree of customer-centricity in organizational strategies and project execution.

H. Performance measurement and reuse of experience: This final characteristic examines the extent to which firms systematically evaluate their performance and apply lessons learned from past projects. The average score reflects the industry's capacity for performance monitoring, knowledge management, and continuous improvement.

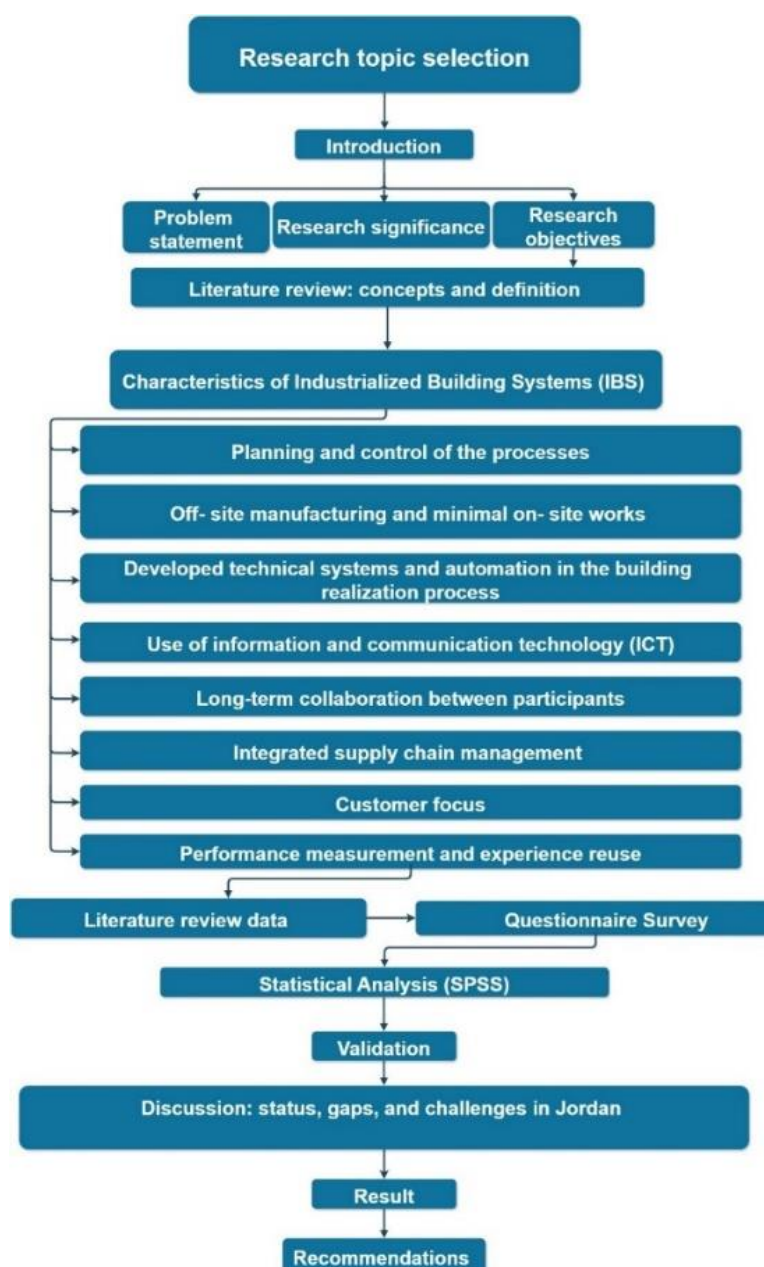


**Figure 1.** Research Stages

### 3.2. Validity Assessment

Prior to statistical analysis, the dataset was examined to ensure its suitability. The screening process included checks for respondent misconduct, missing values, missing data, and normality for a reliable and clean data set. The normality of the data was confirmed through Skewness and Kurtosis tests, with data

being normal if both are between -3 and +3 [33, 34]. Hence, it is inferred that the collected data exhibits no non-normality.

### 3.3. Reliability Assessment

Reliability is the measure of internal consistency of the constructs in the study. Construct reliability was evaluated using Cronbach's Alpha, with a threshold value of  $\alpha \geq 0.70$  indicating acceptable internal consistency [34]. The results demonstrate satisfactory to excellent reliability across all measured categories. Category One and Two, exhibited good internal consistency ( $\alpha = 0.852$  and  $0.843$  respectively), while Category Three and Four, showed excellent reliability ( $\alpha = 0.920$  and  $0.898$  respectively). Category Five, also demonstrated strong reliability ( $\alpha = 0.863$ ). Similarly, Category Six, achieved satisfactory internal consistency ( $\alpha = 0.833$ ). Category Seven and eight both met the minimum acceptable reliability threshold, with Cronbach's Alpha values of  $0.712$  and  $0.781$ , respectively.

## 4. Results and Discussion

### 4.1. Planning and Control of the Processes

The results presented in Figures 2 and 3 provide a comprehensive picture of planning and control practices in the Jordanian housing sector, revealing a combination of structured management and limited standardization across projects. With respect to process definition and planning clarity (Q1-Q6), Figure 2 indicate a relatively high level of agreement among respondents. Many projects are reported to follow a defined process path (Q1), operate according to specific timetables (Q2-Q3), and adopt clear organizational and task structures (Q4-Q5), with planning activities commonly initiated during the early project phase (Q6). Agreement levels across these questions are consistently higher than disagreement, suggesting a general awareness of formal planning principles and basic project management practices. However, the notable proportion of neutral responses indicates that the application of these practices is uneven and not consistently institutionalized across all housing projects.

As shown in Figure 3, responses related to roles and operational control (Q7-Q8) demonstrate relatively strong agreement. Most respondents indicate that responsibilities for issuing instructions are clearly defined (Q7), confirming the existence of hierarchical decision-making structures. In addition, agreement regarding the evaluation and recording of project outputs (Q8) reflects an awareness of feedback mechanisms and basic documentation practices, indicating a reasonable level of managerial discipline at

the project level.

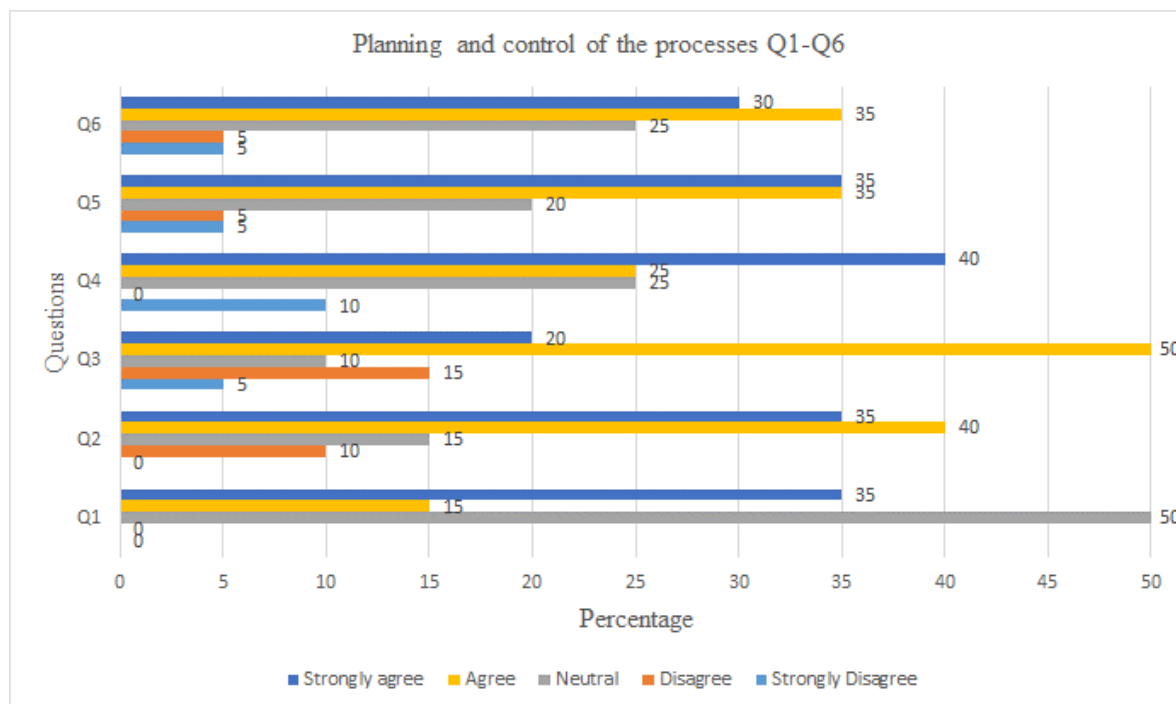


**Figure 2.** Planning and control of the processes Q1-Q6

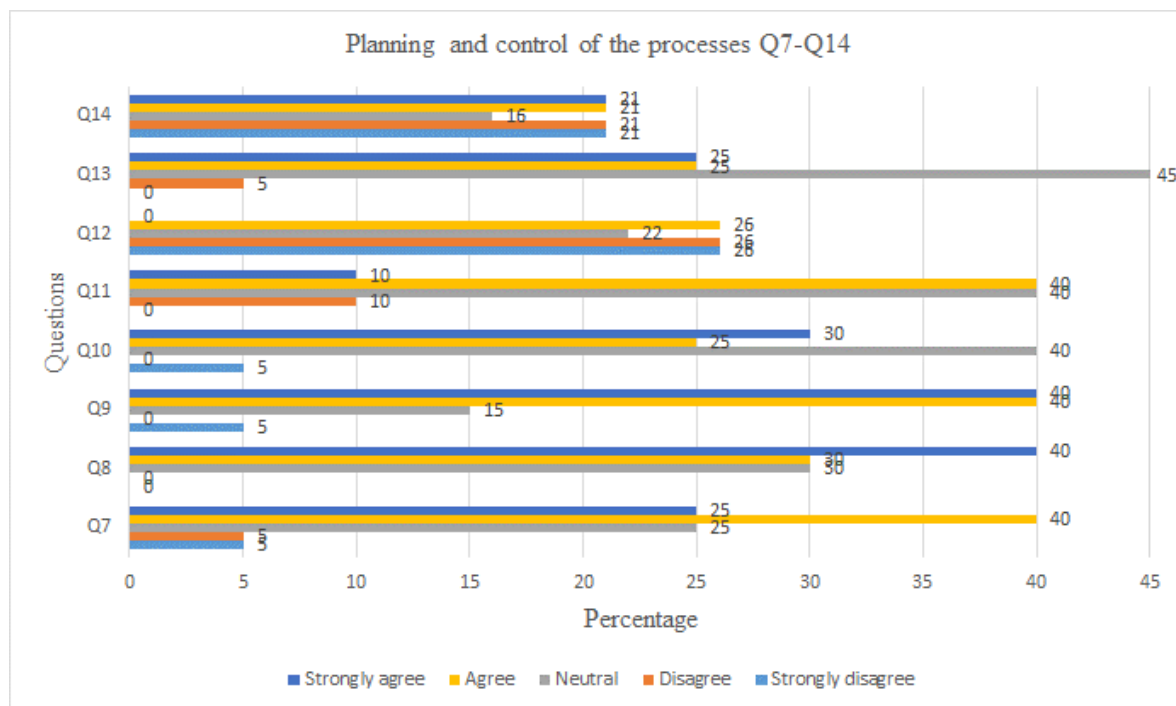


**Figure 3.** Planning and control of the processes Q7-Q14

In contrast, responses related to performance measurement and process standardization (Q9-Q13) exhibit greater variability. While some respondents report measuring building performance against expected outcomes (Q9) and using measurement tools during layout planning (Q10), high levels of neutrality suggest that such practices are not systematically or uniformly applied. Notably, responses to

Q11 and Q12 reveal a critical insight: respondents simultaneously acknowledge both similarities and differences in production lines across projects. This indicates that although certain standardized practices may exist, project-specific conditions continue to drive variations in construction processes. This interpretation is further supported by Q13, which suggests that basic criteria are not consistently maintained across housing projects, highlighting limited standardization at the system level.

Finally, responses to Q14 indicate that modifying the construction sequence after project commencement is generally feasible. While this flexibility allows firms to respond to changing conditions, it also reflects a process environment that lacks rigid control and standardized sequencing typical of fully industrialized construction systems.

Overall, the findings demonstrate that while fundamental planning and control mechanisms, such as task identification, responsibility assignment, adherence to schedules, and early-stage planning, are widely recognized and applied, higher-level practices related to process standardization, consistent performance measurement, and cross-project replication remain underdeveloped. The coexistence of structured project management and operational flexibility suggests a semi-industrialized planning environment, in which formal controls exist at the project level but have not yet been fully institutionalized across the housing sector.

#### **4.2. Use of Prefabricated Elements Off-Site**

Figure 4 presents findings related to the use of prefabricated elements off-site in the Jordanian housing sector. Responses to Q1, which addresses the general use of precast materials on construction sites, are evenly distributed across the Likert scale. This distribution indicates that although prefabricated elements are applied in practice, the decision to employ precast elements appears to be project-specific and influenced by individual contractor preferences or contextual project requirements rather than an established sector-wide approach. Respondents indicated that when prefabrication is adopted, it is mainly limited to structural elements, followed by wall elements, reflecting a selective and function-specific application rather than a comprehensive prefabrication strategy.

Responses to Q2, which addresses challenges related to transporting prefabricated units, clearly indicates a low level of reliance on off-site manufacturing and confirms the continued dominance of traditional, on-site construction methods. Furthermore, responses to Q3 addresses challenges related to transporting prefabricated units, point to logistical constraints as a key influencing factor. These findings

suggest that transportation complexity may limit the use of larger or more diverse prefabricated components, encouraging contractors to confine off-site production primarily to structural frameworks while completing other construction activities on site.

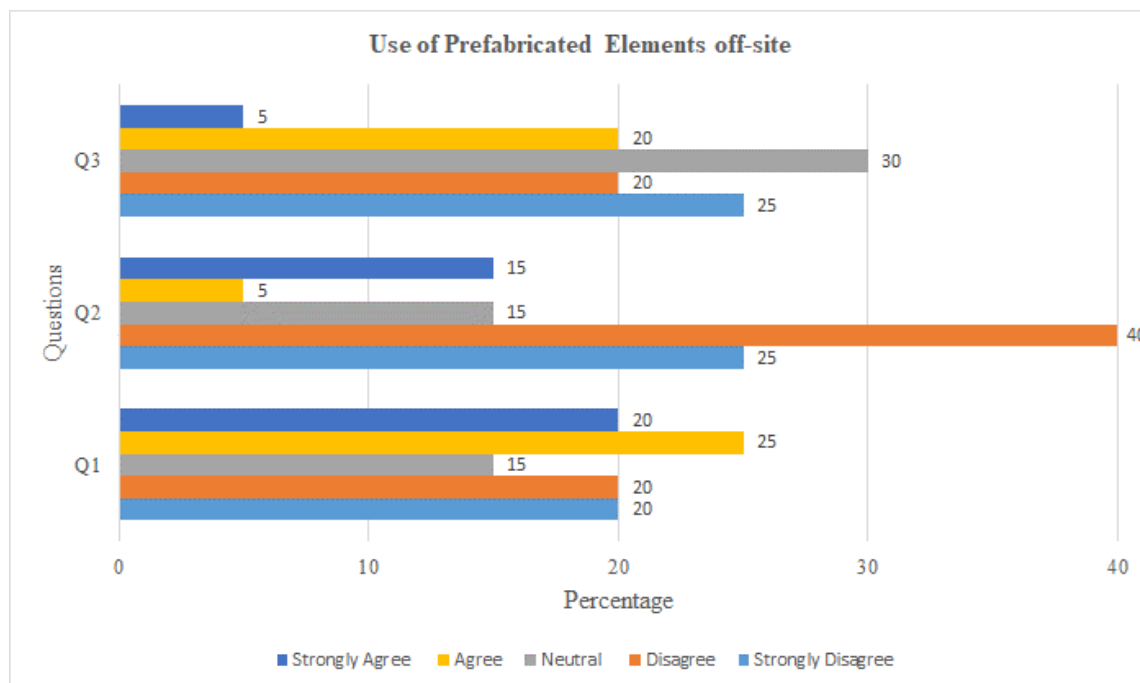


**Figure 4.** Use of prefabricated elements off-site

Overall, the limited and selective application of off-site production practices may be attributed to several interrelated factors. These include limited familiarity with the benefits of industrialized construction among firms and clients, logistical challenges associated with transportation and handling, and concerns related to safety and implementation risk. In addition, insufficient trust in prefabricated technologies among clients may further constrain their broader adoption. Collectively, these findings highlight the need for increased awareness, supportive policy incentives, and improved infrastructural and logistical frameworks to promote the wider integration of off-site construction techniques within Jordan's building industry.

### 4.3. Advanced Technical Systems and Automation

Figure 5 presents respondents' perceptions of advanced technical systems and automation in housing projects based on Q1-Q12. Results reveals a clear contradiction within the Jordanian housing sector. At the design level, many characteristics align with the principles of industrialized housing. For example, there is strong agreement that apartment layouts exhibit symmetry (Q12) and that structural systems are consistently applied across projects (Q6), both of which are fundamental prerequisites for efficient, factory-based production and process repetition.

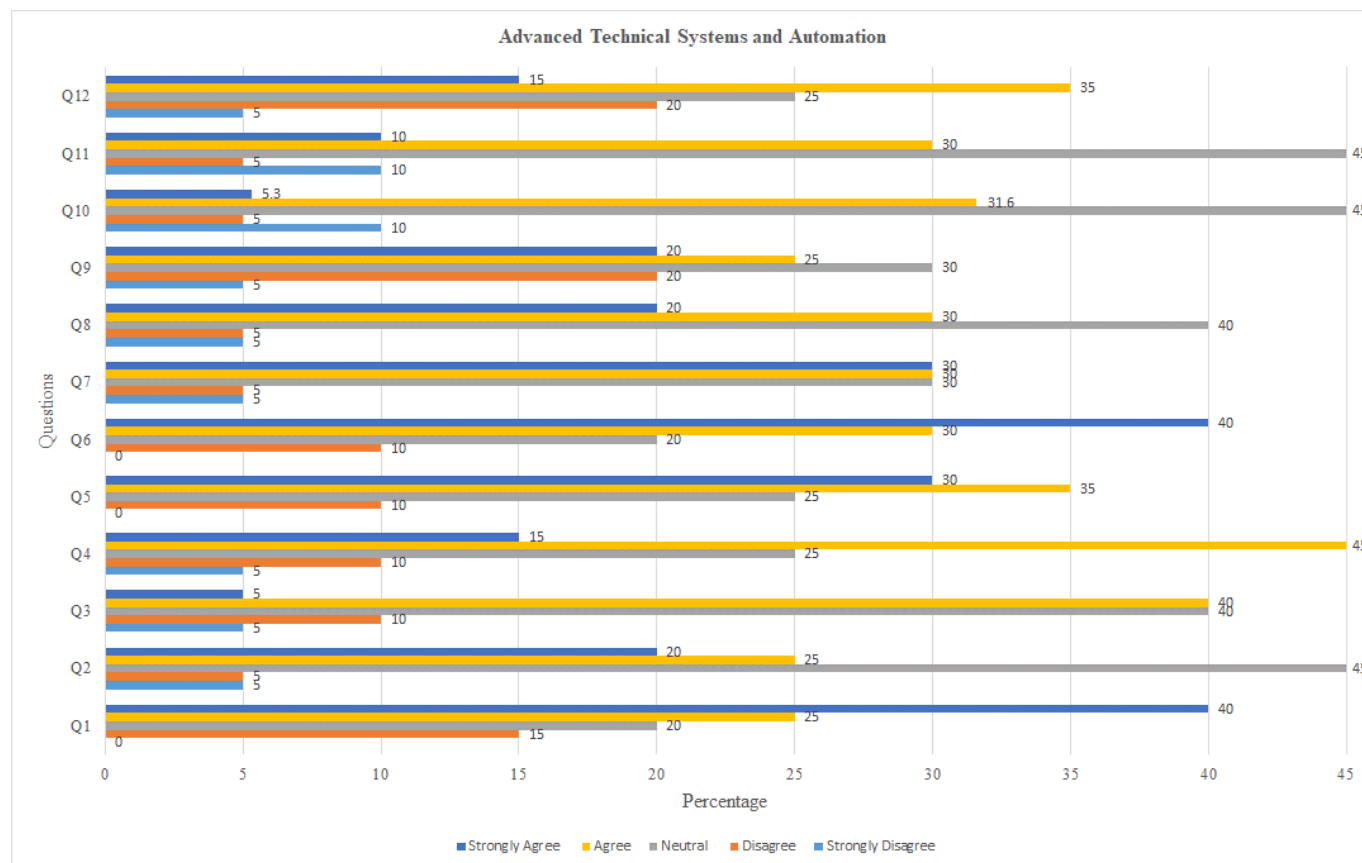


**Figure 5.** Advanced Technical Systems and Automation

However, on-site construction practices diverge markedly from these design intentions. Despite the presence of repetitive and standardized designs, there remains a strong dependence on manual, labor-intensive methods and confirming the limited usage of automated or mechanized construction techniques (Q1). A particularly revealing finding emerges from Q7, which addresses whether floor slabs are poured simultaneously across entire housing units. The overwhelming disagreement indicates that construction activities are executed in segmented stages rather than through continuous or synchronized processes, underscoring the persistence of conventional, labor-intensive construction methods.

Moreover, responses to more detailed technical aspects, such as subsystem integration (Q9) and the unification of entrance design and construction materials (Q11) are dominated by neutral positions. This suggests that while primary structural systems are standardized, secondary systems, finishes, and technical components are implemented in a project-specific and inconsistent manner. Collectively, these findings indicate that although the housing sector in Jordan exhibits formal characteristics of industrialization at the design level, its execution remains largely rooted in traditional construction practices, resulting in a hybrid model that combines standardized forms with non-industrialized production processes.

#### 4.4. Use of Information and Communication Technology

Figure 6 illustrates respondents' perceptions of ICT usage in construction practice based on Q1-Q6. The findings indicate that the Jordanian construction sector demonstrates a relatively high level of technological capability, particularly in the use of ICT tools. Clear agreement is observed regarding the use of basic digital equipment such as computers and printers (Q3), while an even higher proportion of respondents report extensive use of advanced design software, including CAD and Revit (Q4). In addition, electronic communication tools such as email and online networking platforms are frequently utilized (Q5-Q6), highlighting the widespread adoption of digital communication practices.

Overall, while ICT adoption in the Jordanian construction sector is well established, particularly in design and communication, there remains significant potential to expand its use toward more advanced applications, including document management, logistics integration, and customer engagement.

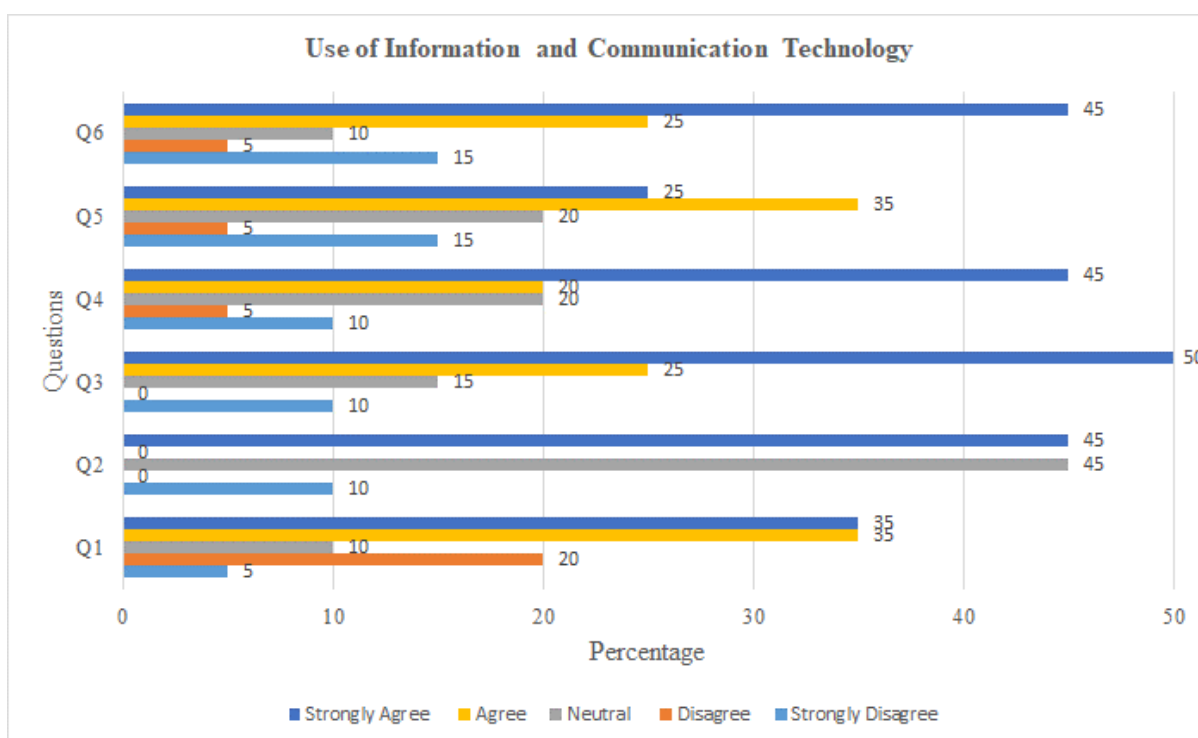


**Figure 6.** Use of Information and Communication Technology

#### 4.5. Long-Term Relations Between Participants

Figure 7 presents responses related to the characteristics of long-term relationships between project participants in the Jordanian construction industry. A notably high proportion of neutral responses characterizes responses to (Q1-Q2). This pattern suggests that inter-organizational relationships are largely transactional in nature, with collaboration typically limited to the duration of a specific project. Once project

objectives are achieved, these relationships often dissolve, indicating weak institutionalization of long-term partnerships. Overall, the findings provide limited evidence of sustained, strategic collaboration across firms within the sector.

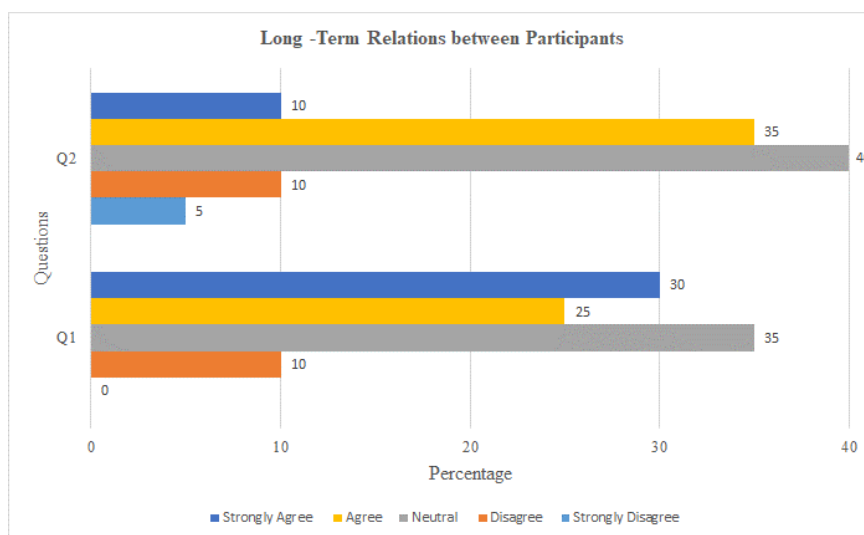


**Figure 7.** Long-term relations between participants (Q1-Q2)

Moreover, Q3 examine the nature and duration of relationships among key project stakeholders. The results indicate a clear preference for medium-term collaboration over long-term partnerships, as shown in Figure 8, where the medium-term option was selected most frequently, substantially exceeding both short-term and long-term alternatives.

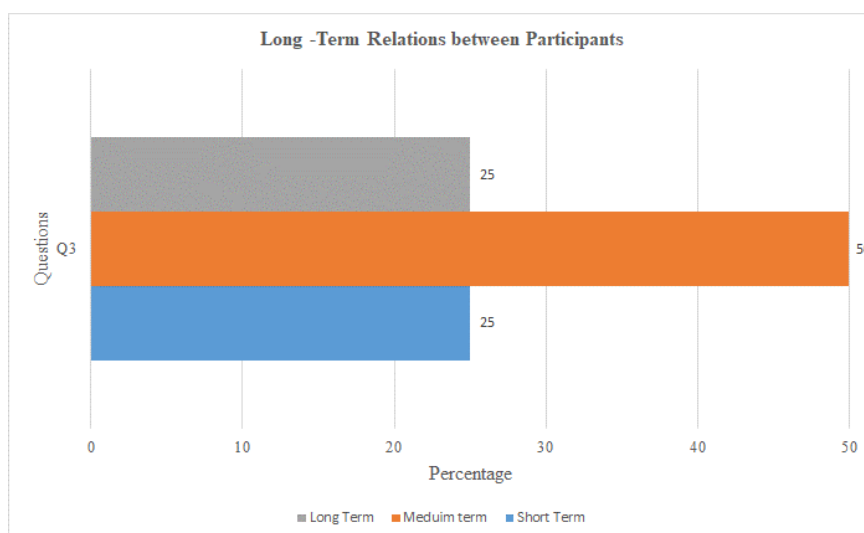


**Figure 8.** The nature and duration of relationships

Overall, findings indicate that the construction industry is adopting integrated teamwork and collaboration; however, it may benefit from further investment in structured programs to support sustainable long-term partnerships. Such initiatives could enhance project coordination, improve

stakeholder communication, and contribute to more efficient and consistent project delivery.

#### 4.6. Customer Focus at the Centerpiece of the Design

Figure 9 presents the findings related to customer focus within the context of industrialized housing in Jordan. Overall, the results indicate a moderate level of customer consideration, accompanied by limitations in translating customer input into tangible design and production outcomes.

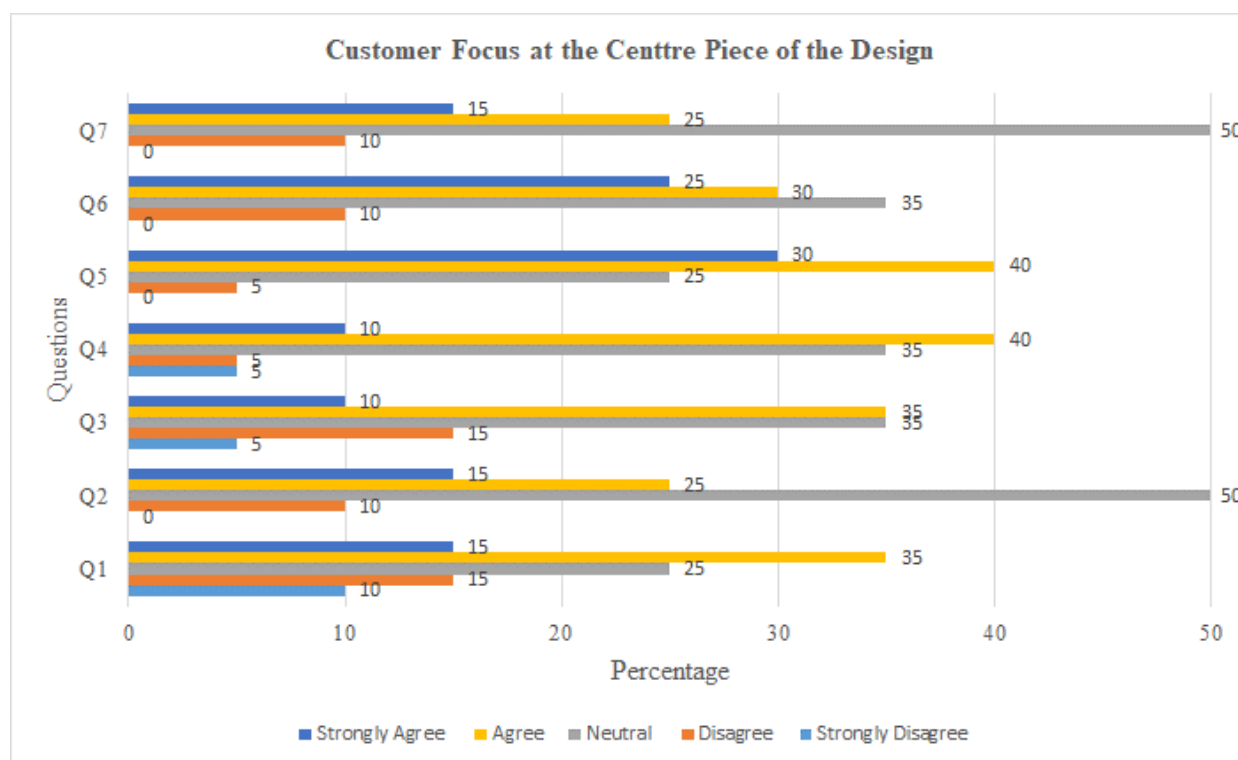


**Figure 9.** Customer focus at the centerpiece of the design

Responses concerning the influence of clients on design decisions reveal a degree of ambiguity. Nevertheless, there is strong agreement regarding the implementation of customer surveys (Q1) and follow-up practices (Q5), suggesting that organizations demonstrate a clear intent to listen to and understand customer needs. These findings indicate that mechanisms for collecting customer feedback are generally in place.

However, when examining the characteristics of the final housing product, the results point to a more rigid approach. High levels of neutrality in responses related to standard house sizes (Q2) and predefined design models (Q7) suggest that, despite acknowledging customer input, companies do not consistently modify established design templates to reflect individual preferences. This pattern reflects a production logic closer to mass production, in which customer feedback is considered but largely accommodated within conventional and standardized models rather than through fully customized solutions.

The relatively modest emphasis on translating survey outcomes into flexible design alternatives and standardized modular options indicates significant potential for improvement. Enhancing customer integration during the planning and production stages, through more systematic needs assessments and adaptable design frameworks, could substantially improve product quality, operational efficiency, and market responsiveness in Jordan's industrialized housing sector.

#### 4.7. Supply Chain Management Integrated in the Construction Process

Figure 10 presents the survey findings related to supply chain management integration, while Figure 11 provides further insight into the nature of material flow within this context. From a relational perspective, the findings are generally positive. A large proportion of respondents “Agree” or “Strongly Agree” that they maintain direct and clear relationships with suppliers (Q6). In addition, responses to Q4 indicate that information exchange between contractors and suppliers is effective, suggesting that communication channels are well established and function adequately at the interpersonal level.

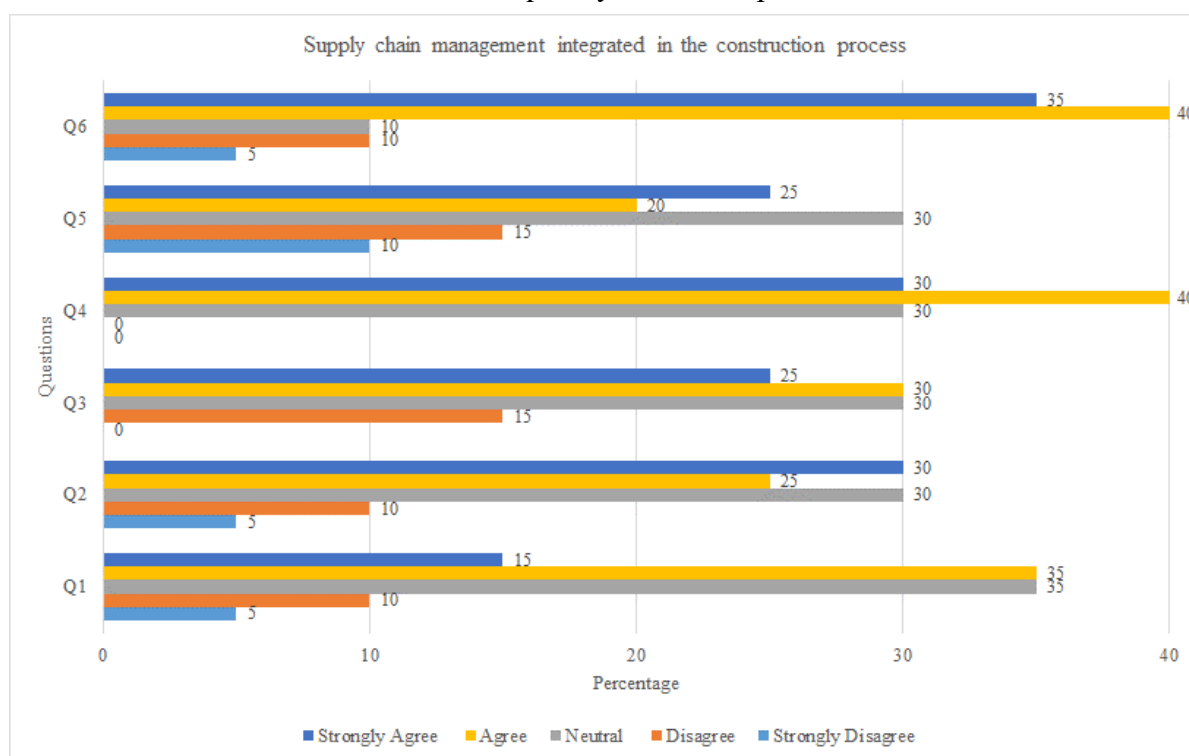


**Figure 10.** Supply chain management integrated in the construction process

In contrast, responses related to technological and procedural integration reveal notable limitations. High levels of “Neutral” responses to questions concerning IT support for logistics (Q3) and the integration of logistics activities within the construction process (Q1) indicate that advanced digital tools and coordinated logistics systems are not widely adopted. This reliance on informal coordination is further

reinforced by Figure 11, which shows that material supply is frequently irregular or conducted on an as-needed basis, with only a small proportion of respondents reporting a regular and stored supply of materials.

Collectively, these findings indicate that material logistics in Jordan's housing sector are largely reactive rather than systematically planned and controlled. While strong supplier relationships and effective communication exist, logistics planning, particularly with respect to storage management and regularized material flow, remains underdeveloped. Strengthening logistics integration through the adoption of advanced logistics management tools, formalized inventory systems, and improved storage practices could substantially strengthen the efficiency and resilience of the construction supply chain.

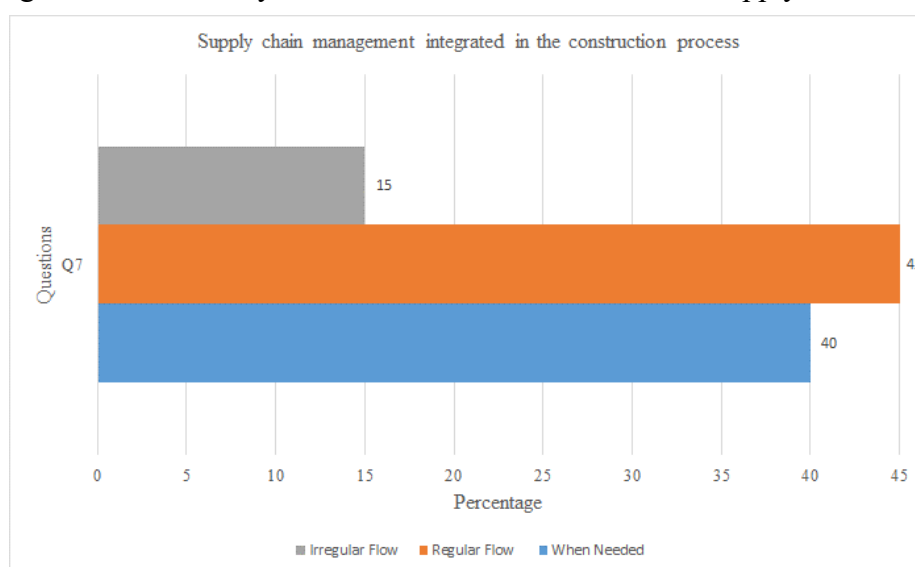


**Figure 11.** The nature of material flow

#### 4.8. Measuring Organized Performance and Reuse of Experience

Figure 12 presents the findings related to the measurement of organized performance and the reuse of experience within Jordan's residential construction sector. The results provide insight into both the prevalence of performance evaluation practices and the extent to which such evaluations inform organizational learning. Responses to Q1 indicate high levels of agreement that performance and experience are measured, suggesting a strong awareness among firms of the importance of evaluating past project outcomes. This reflects a positive orientation toward feedback and performance monitoring within the sector.

However, Figure 13 shows a closer examination of Q3, which addresses the methods used for performance measurement, reveals notable limitations. The dominant response indicates that performance is primarily assessed through meetings, pointing to a reliance on informal, discussion-based evaluation

practices. This suggests that performance measurement is largely qualitative and lacks systematic, data-driven tools or standardized metrics. Furthermore, responses to Q2 show a high proportion of Neutral selections, indicating that although performance is measured, its influence on modifying work models and improving standard systems is limited or unclear.

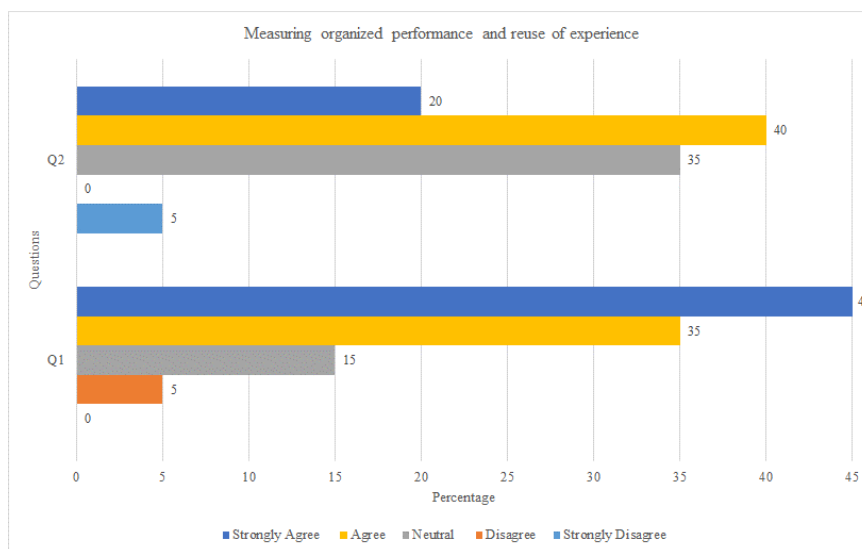


**Figure 12.** Measuring organized performance and reuse of experience

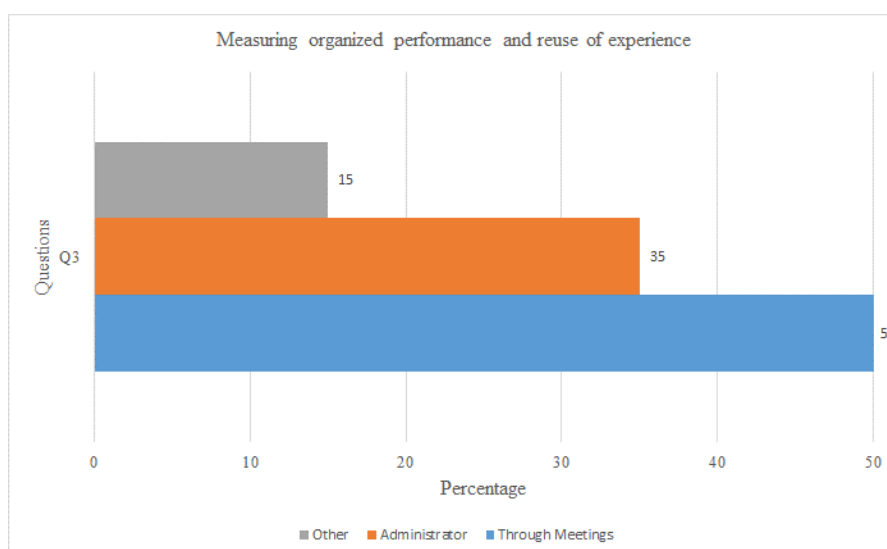


**Figure 13.** The methods used for performance measurement

Collectively, these findings suggest a disconnect between performance evaluation and organizational learning. While companies actively engage in performance measurement, the outcomes of these efforts are not consistently translated into structured improvements or process optimization. The adoption of more formalized performance management approaches, such as key performance indicators (KPIs), benchmarking frameworks, and data-driven analytical tools, could enhance the effective reuse of experience. Integrating performance measurement outcomes into operational models and decision-making

processes would further support continuous improvement and long-term efficiency in the residential construction sector.

Figure 14 presents a comparative analysis of the application of industrialized building characteristics across housing companies in Jordan. The hand box plot illustrates the distribution of application levels for each of the eight characteristics, capturing minimum, maximum, and median values. It reveals substantial variation in implementation across companies, with the widest range observed in planning and control, indicating that this component is applied to varying degrees but with relatively high engagement overall. Similarly, performance measurement and reuse of experience also show a high median value, reflecting their prominence among surveyed firms. In contrast, characteristics such as technical building components, use of ready-made elements, and long-term relationships exhibit consistently lower ranges and median values, suggesting limited adoption across the sector. These findings are corroborated by the bar chart as shown in Figure 15, which displays the percentage of application for each component. It indicates that planning and control, information management, and performance measurement are the most widely applied characteristics, while readymade elements and technical components are among the least implemented, with application levels under 30%.

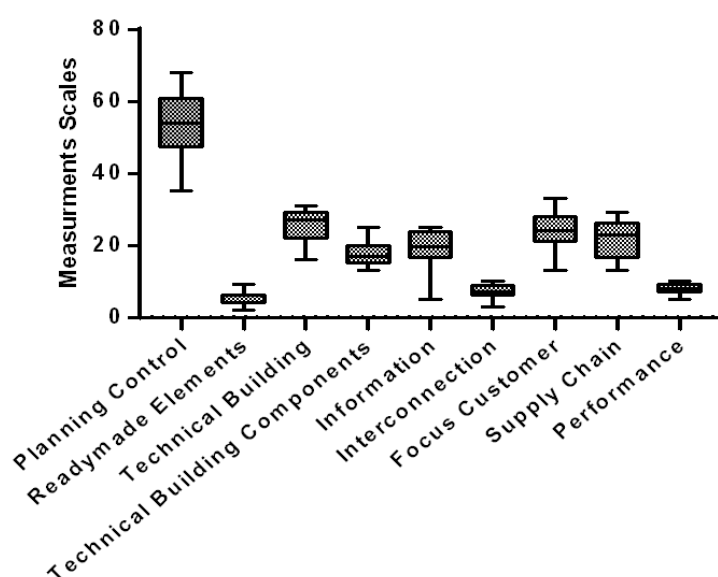


**Figure 14.** Distribution of Industrialized Construction Characteristics

The mean and standard deviation values associated with the least-applied components reported as approximately  $5.5 \pm 1.8$  and  $7.1 \pm 1.6$  highlight the relatively low and concentrated use of these practices among firms. Despite this variability, the results suggest an emerging trend toward industrialized housing practices in Jordan. Several companies have begun to adopt new construction models aimed at improving

efficiency and product quality. However, broader integration of industrial building principles, particularly those related to off-site construction, prefabrication, and structured supply chain management, remains a key area for development. Enhanced standardization and investment in industrialized techniques may support long-term improvements in housing production, economic performance, and overall project outcomes.

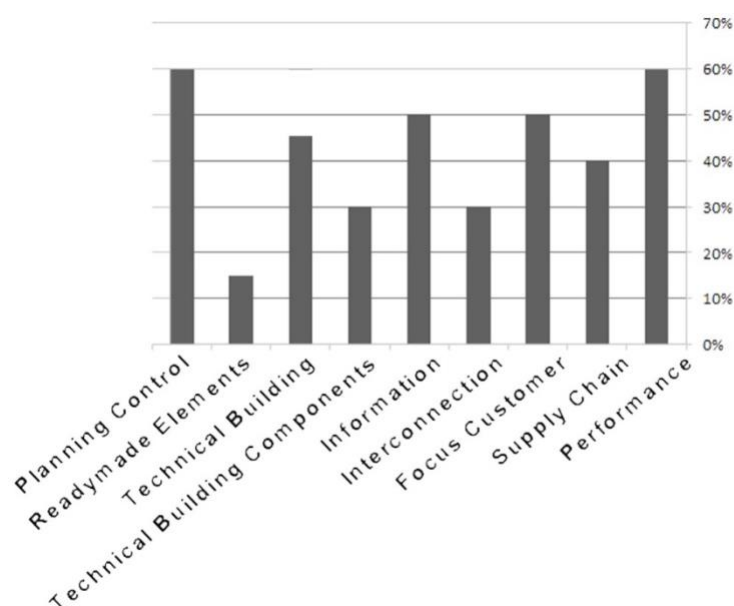


**Figure 15.** Application Percentage of Industrialized Construction Components

## 5. Conclusions

In conclusion, this research offers a critical assessment of the current state of industrialized building practices within the housing sector in Jordan, highlighting substantial gaps between the ideal characteristics of industrial construction and their practical implementation. The findings reveal that the absence of a clear strategic vision and systematic processes within the construction industry significantly restricts the adoption of advanced technologies and innovative practices. The continued dependence on conventional construction methods further exacerbates this issue, presenting a major obstacle to the sector's industrial transformation.

The limited application of key industrial features such as prefabricated components, integrated technical systems, and collaborative stakeholder partnerships underscores the need for increased awareness, professional training, and a shift in organizational culture. Addressing these challenges requires the adoption of modern construction technologies, standardized administrative systems, and best practices aligned with international benchmarks. A transition toward industrialized construction offers a promising

solution to the housing and reconstruction demands in Jordan; however, it requires collaborative efforts between public and private sectors.

This study underscores the demand for transformation within the housing industry, presenting it as both an essential requirement and a strategic opportunity for performance improvement. By addressing the identified challenges and fostering a culture of innovation and continuous improvement, the construction sector can significantly improve productivity, efficiency, and quality outcomes. To achieve these objectives, policymakers, construction firms, professionals, and end users must collaborate in developing comprehensive strategies that promote the adoption of advanced technologies, strengthen long-term partnerships, and prioritize customer needs. Through such efforts, Jordan can position itself as a leader in industrialized construction, delivering sustainable, high quality housing while supporting broader economic development goals.

**Data Availability Statement:** The data supporting the findings of this study are included within the article. Additional survey data are available from the corresponding author upon reasonable request.

**Funding:** The authors declare that no funding was received for this research.

**Declaration of Competing Interest:** The authors declare that they have no known competing interests.

**Research Involving Human/Animal Participants:** The study involved a questionnaire survey of construction professionals. Ethical approval was obtained from the relevant ethics committee at Jordan University of Science and Technology. Informed consent was obtained from all participants before data collection. All responses were collected voluntarily and used anonymously for research purposes. This article does not involve any animal studies.

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