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UNLOCKING EFFICIENCY IN TIMBER FRAME CONSTRUCTION: A COMPARATIVE STUDY OF ON-SITE VS. OFF-SITE APPROACHES IN SCOTLAND

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ABSTRACT

This study evaluates the effectiveness of on-site versus off-site timber frame construction (TFC) for low-rise housing in Scotland, specifically addressing sustainability, cost, time efficiency, and quality control to support the Scottish government's target of delivering 110,000 affordable homes by 2032. Data were collected using a mixed-methods approach, comprising a quantitative survey of 100 construction professionals and qualitative interviews with two senior industry managers. The quantitative data were analysed using statistical methods, including frequency and mean analysis, while the qualitative data were analysed using thematic analysis. The findings reveal that off-site offers advantages in terms of time efficiency and quality control, reducing on-site labour and ensuring consistent production. However, high initial costs and logistical challenges hinder widespread adoption, particularly in remote areas. On-site TFC remains more adaptable and cost-effective in such regions, benefiting from readily available labour and material flexibility. Sustainability outcomes varied based on material usage and transportation, with off-site reducing waste but often using less eco-friendly insulation. While 80% of respondents favoured off-site for quality control, concerns about insulation settlement and moisture risks existed. Accordingly, the choice between on-site and off-site methods depends on project scale, location, and budget. Off-site is better suited for large-scale developments, while on-site methods remain practical in rural areas. This study contributes by highlighting the importance of context-specific considerations in choosing construction methods and supports the strategic alignment of TFC practices with Scotland's housing targets.

Keywords: *Cost and Time Efficiency; Off-Site Prefabricated Construction; On-Site Timber Frame Construction; Sustainability; Quality Control.*

1. INTRODUCTION

The UK construction industry faces persistent challenges, particularly in the domestic housing sector, where the supply of affordable homes fails to meet increasing demand. The UK Government has set a target of constructing 300,000 new homes annually in

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England to address this shortfall; however, only approximately 233,000 homes were completed in 2021/22 (UK Parliament, 2023). Similarly, Scotland has established its housing targets to deliver 110,000 affordable homes by 2032, averaging approximately 12,222 homes annually, with at least 70% designated for social rent (Scottish Government, 2025a). The housing crisis in both contexts is driven by population growth, unsuitable housing stock, and economic constraints (UK Parliament, 2023; Scottish Government, 2025a).

This research investigates the effectiveness of on-site and off-site prefabricated TFC methods specifically for low-rise domestic dwellings in Scotland, assessing their potential to contribute to meeting the Scottish Government's housing targets. A significant proportion (77.9%) of the UK population resides in houses or bungalows, reinforcing the need for efficient construction methods (ONS, 2023). While on-site TFC is widely utilised, closed-panel off-site manufacturing is increasingly adopted due to advantages related to labour availability, material supply, and regulatory support (Duncheva & Bradley, 2019). Scotland, notably, exhibits high adoption rates of TFC, accounting for 85% of the housing market, compared to only 23% in the rest of the UK (Structural Timber Association, 2023).

Both on-site and off-site construction methods offer distinctive advantages. Traditional on-site timber frame systems typically serve as load-bearing structures requiring additional insulation and finishing. In contrast, prefabricated off-site panel systems are highly engineered, pre-assembled, and enable faster erection with superior thermal efficiency, achieving U-values as low as 0.10 W/m²K compared to approximately 0.15 W/m²K for on-site construction (Structural Timber Association, 2023). Despite these recognised benefits, existing research rarely evaluates how specific geographic, economic, and logistical contexts within Scotland influence the comparative effectiveness of these timber construction methods, highlighting a critical knowledge gap.

Addressing this gap, this study aims to evaluate and compare the effectiveness of on-site versus off-site TFC methods in Scotland, specifically assessing their relative performance against sustainability, cost, construction time, and quality control criteria, to determine their potential to support Scotland's target of delivering 110,000 affordable homes by 2032. The paper is structured sequentially to ensure logical coherence; Section 2 reviews literature and identifies research gaps, shaping the research aim and methodology (Section 3). Findings from surveys and interviews are presented (Section 4), informing a discussion (Section 5) linked to theory and practice. Section 6 provides actionable conclusions and recommendations for Scotland's housing sector.

2. LITERATURE REVIEW

TFC has a long-standing presence in the building industry, particularly praised for sustainability benefits stemming from its near carbon-neutral profile (Palma & Steiger, 2020). The UK's housing crisis has renewed interest in off-site prefabrication methods as potential solutions due to their efficiency, speed, and reduced dependency on skilled labour (Menendez et al., 2011; Shibani et al., 2021). Despite these recognised benefits, adoption across the UK remains uneven, with only 9% in England versus 92% in Scotland (DEFRA, 2025), highlighting regional variances influenced by economic, geographic, and logistical contexts. However, existing literature frequently overlooks detailed, context-specific comparisons between on-site and off-site timber frame methods within

Scotland, particularly regarding their practical viability, sustainability, cost-effectiveness, and quality control. Recent studies, such as those by Mackenzie and Bell (2025), emphasise the growing need for localised research to enhance the understanding of regional construction contexts. Although numerous studies broadly address the advantages of prefabrication, they rarely investigate how unique regional factors, such as geographic location, availability of skilled labour, transport infrastructure, and local economic conditions, directly influence method selection and effectiveness. This gap limits the practical utility of existing research for Scottish policymakers and construction professionals facing the specific challenges of achieving ambitious housing targets in diverse Scottish contexts.

Construction is vital to the UK economy, employing 231,000 people in Scotland in 2021 and generating £13.3 billion in output (CIOB, 2024). As of 2025, Scottish construction output is projected to reach £14.1 billion, driven largely by ongoing housing and infrastructure investments (Scottish Government, 2025a). The government has pledged £44 billion in housing investment (Department for Business and Trade, 2019). Investments in manufacturing aim to boost speed, safety, and productivity, though skills shortages remain, despite apprenticeship growth from 22,500 in 2018/19 to 33,600 in 2022/23 (CIOB, 2024). Off-site prefabrication, valued at £6 billion, makes up less than 6% of UK construction (George et al., 2022). A 2023 NBS survey showed that over half of professionals had used off-site methods (NBS, 2023). Reported benefits include faster build times, better material control, and reduced reliance on skilled labour, supporting sustainability goals (NBS, 2023).

Globally, countries like Sweden, Japan, and New Zealand have embraced off-site TFC, often achieving higher efficiencies than the UK (Smith, 2010). A recent comparative analysis by O'Connor and Mitchell (2025) underlines that targeted policy interventions and robust supply chains remain essential for successful adoption, highlighting lessons Scotland could integrate into its housing strategies. These comparisons highlight the importance of systemic adoption, local manufacturing support, and cultural acceptance in successful implementation.

2.1 GOVERNMENT INCENTIVES FOR MODERN CONSTRUCTION METHODS

Government intervention plays a crucial role in promoting off-site construction. The Science and Technology Select Committee's report, Off-site Manufacture for Construction: Building for Change (2018), identified several industry challenges, including low productivity, structural fragmentation, narrow profit margins, limited training, an ageing workforce, and a poor industry image (UK Parliament, 2018). Furthermore, the Department for Business, Innovation and Skills (2013) reinforced commitments to prefabrication through funding, regulatory reforms, and enhanced industry collaboration to address persistent productivity and skills challenges. To address these issues, the Infrastructure and Projects Authority (IPA) released the Transforming Infrastructure Performance report (2017), which prioritises investment, productivity improvements, and maximising infrastructure outcomes (Infrastructure and Projects Authority, 2017). In addition, the Industrial Strategy White Paper (2017) set ambitious targets for the construction sector, such as a 33% reduction in lifecycle costs, a 50% cut in construction time and greenhouse gas emissions, and a 50% reduction in the trade gap for construction materials (HM Government, 2017).

2.2 COMPARATIVE ANALYSIS OF ON-SITE VS. OFF-SITE TFC

2.2.1 Sustainability

The built environment sector is a major contributor to greenhouse gas emissions, accounting for 37% globally and 40% in the UK. This is mainly due to the cement and metal production (United Nations Environment Programme, 2023). Moreover, the industry generates 60% of the UK's waste and emits 50 million tonnes of CO_2 annually (Government Commercial Function, 2021). Recent sustainability audits in Scotland emphasise the pressing need for construction innovations that reduce emissions and waste, placing prefabrication prominently in the policy discourse (Scottish Government 2025b). With the growing concerns in sustainable and environmentally responsible building, prefabricated construction methods provide sustainability benefits by minimising waste and improving energy efficiency (Pons, 2014). Even though there are benefits to prefabricated construction, Liu et al. (2022) argue that challenges like high carbon emissions from element manufacturing persist.

On-site timber construction, on the other hand, offers much greater material flexibility and often relies on local resources, reducing transportation-related emissions (Nikologianni et al., 2022). Timber construction also supports carbon sequestration, preventing approximately 3.9 tonnes of CO_2 emissions per tonne of wood used. Moreover, Scotland's 2023 carbon reduction laws promote sustainable materials like timber, which can be recycled more efficiently than some prefabricated components (Hart et al., 2019).

2.2.2 Cost

Cost remains a critical factor in construction decisions. The UK construction industry, valued at £138 billion, employs over 3.1 million people (ONS, 2025). Inflation, supply-chain issues, rising material costs, and geopolitical tensions have notably increased delays and expenses (Crichton, 2025). Off-site TFC is increasingly recognised as offering substantial cost-saving potential, particularly through reducing on-site construction durations, minimising waste, streamlining material management, and mitigating risks such as theft and damage (J-Engineering, 2024). Consequently, prefabrication tends to be highly cost-effective, particularly for repetitive construction formats such as flats and multi-unit developments. Despite these advantages, Current estimates indicate upfront costs for prefabricated methods remain around 7-10% higher than conventional approaches (Connected Places Catapult, 2019). However, recent industry perspectives increasingly recognise that these initial costs are offset through lifecycle efficiencies, enhanced quality control, and reduced operational costs over time (J-Engineering, 2024).

2.2.3 Time Efficiency

One of the most significant advantages of off-site timber construction is its ability to significantly reduce project timelines, with some estimates indicating up to a 50% reduction compared to traditional methods (Hashemi, 2013). Faster completion lowers costs and allows developers to allocate resources more efficiently to other projects. Recent evaluations by McGregor and Sinclair (2025) confirm these time efficiencies, particularly in large-scale residential projects across Scotland.

2.2.4 Quality Control

Quality control is a crucial consideration in construction and is particularly challenging in on-site construction, where human errors and weather exposure can lead to costly delays (Carnegie Mellon University, 2014) . Scotland's unpredictable climate poses risks to prefabricated timber frame buildings during transport and erection. New studies have recommended enhanced logistics strategies to minimise these risks, emphasising controlled transport and rapid assembly processes to improve quality outcomes (Scottish Timber Industry Association, 2025).

3. RESEARCH METHODOLOGY

This study employed a mixed-methods approach, combining both quantitative and qualitative research to evaluate the application of on-site and off-site TFC. This approach comprehensively integrates numerical data with contextual insights (Creswell & Plano Clark, 2023). The quantitative component offered measurable data for statistical analysis, enabling the identification of trends and general patterns (Bryman, 2016), while the qualitative component captured the in-depth experiences and views of industry practitioners. Primary data were collected via a structured questionnaire sent to 120 experienced construction professionals, including site managers, architects, contractors, and surveyors, yielding 100 responses. Descriptive statistical methods, such as frequencies and percentages, ensure analytical rigour and identify key trends. Given the study's exploratory nature, these methods provided a straightforward yet robust foundation for understanding industry perceptions across sustainability, cost, time, and quality control dimensions. Additionally, semi-structured interviews were conducted with two industry experts (with six decades of experience) from a UK housing development firm to supplement the survey findings with practical insights and sector-specific reflections. The primary reason for selecting two interview participants in this study is that the value of these interviews lies in the quality and specificity of the information obtained rather than the quantity, enabling focused and highly relevant insights. Additionally, practical considerations such as time constraints, resource availability, and the limited availability of qualified experts justify limiting the interviews to two participants.

Additionally, the validity of the survey findings was enhanced through triangulation with qualitative interview data. A snowball sampling technique was employed to recruit survey participants. This method, which combines elements of convenience and purposive sampling, was selected for its efficiency in accessing qualified respondents while ensuring the inclusion of information-rich cases (Parker et al., 2019). Table 1 presents the demographic profile of participants, including their professional roles, years of industry experience, and levels of exposure to different TFC systems.

Table 1: Background information of survey respondents

Respondents' attributes	No. of respondents
Profession in the organisation	
Architectural Technicians	57
Building Standards Surveyors	24
Contractor	04

Respondents' attributes	No. of respondents
Site Agent/ Manager	09
Others (Engineers, Quantity surveyors and project managers)	14
Years of experience in the construction industry	
0-5 years	12
5-10 years	14
10-15 years	06
15- 20 years	14
More than 20 years	62

The questionnaire survey was conducted using Microsoft Forms, which enabled the efficient collection of responses while ensuring participant anonymity. This digital platform also facilitated streamlined data management and visualisation (Evans & Mathur, 2005). The questionnaire design combined multiple-choice questions for statistical analysis with open-ended questions to capture qualitative insights, aligning with best practices in mixed-methods research (Creswell & Plano Clark, 2023).

4. RESEARCH FINDINGS

The primary aim of this research was to evaluate and compare the effectiveness of on-site versus off-site TFC methods in Scotland against key criteria such as sustainability, cost, time efficiency, and quality control. Findings from the questionnaire survey and interviews are presented thematically below.

4.1 QUESTIONNAIRE SURVEY FINDINGS

4.1.1 Experience in TFC Methods

Respondents were asked to report their experience with various low-rise domestic construction methods. Results indicated that 66% of participants had extensive experience with on-site TFC, whereas approximately 26% reported experience with off-site prefabricated timber frame systems. This distribution suggests a prevailing industry preference for on-site TFC in Scotland's low-rise domestic housing sector. A smaller group (8%) had experience across multiple construction types, including modular, masonry, and a combination of all methods. These findings are summarised in Table 2, which presents the number of respondents indicating familiarity with each construction method.

Table 2: Respondents' experience in TFC

Low-rise domestic frame construction	Respondents' most experienced
On-site timber frame	66
Prefabricated timber kit	26
Masonry construction	05
Modular construction	01
All of the above	02

4.1.2 Industry Perceptions of the Initial Cost of On-site and Off-site Timber Construction

Respondents expressed divided opinions regarding the cost-effectiveness of on-site versus off-site timber construction. A majority (59%) perceived on-site construction to be more cost-effective, attributing this to lower upfront costs, greater on-site flexibility, and the use of readily available labour and materials. Conversely, 41% of respondents viewed off-site prefabrication as a strategic investment, noting that while initial costs are higher, these are often offset by labour efficiencies, reduced construction time, and improved quality control throughout the project's life.

Key barriers to adopting off-site methods were identified as the higher capital investment required at the outset, along with additional transportation costs, complexity in panel design, and a reliance on specialised equipment, such as cranes, for on-site assembly. These factors continue to influence industry preferences and decision-making, particularly in small- to medium-scale domestic construction projects.

4.1.3 Sustainability Considerations

More than 75% of respondents perceived off-site prefabrication as the more sustainable construction method. Key reasons cited included reduced material waste, improved quality control in factory settings, and enhanced airtightness, all contributing to better energy efficiency. These findings align with broader industry perspectives on the environmental benefits of off-site prefabrication in modern timber construction.

However, a subset of respondents argued that on-site construction could be more sustainable in specific contexts. This view was based on the use of locally sourced materials, reduced transportation requirements, and lower reliance on synthetic or industrially processed materials. Additionally, some participants highlighted that off-site panels often include additional layers, such as insulation sandwiched between two sheets of Oriented Strand Board (OSB), which can increase material usage. In contrast, on-site timber frame walls typically require only a single OSB sheathing layer, which can potentially result in lower overall material consumption.

These contrasting views suggest that the sustainability of timber construction methods may be context-dependent, influenced by factors such as material sourcing, project scale, and regional practices.

4.1.4 Quality Control and Build Time

The findings indicate that approximately 79% of construction professionals believe prefabricated or closed panel systems offer superior quality control compared to on-site methods. Respondents highlighted that factory-controlled environments enable more consistent workmanship and reduce the likelihood of defects due to weather, labour variability, or material handling on site. In contrast, around 21% of participants supported open panel systems, emphasising the benefits of on-site flexibility, particularly where design modifications are needed during construction phases.

Regarding build time, the majority of respondents recognised that off-site construction significantly reduces on-site assembly duration, thereby shortening overall project schedules. Specific advantages cited included *"speed of manufacture and erection" and achieving "wind and watertight stage more quickly."* However, many also cautioned that longer lead times for design finalisation, factory production, and delivery logistics can

offset these advantages. Additionally, a few respondents noted that delays in factory scheduling or site readiness can compromise the efficiency gains typically associated with off-site approaches.

4.1.5 Challenges and Benefits of Construction Methods

Survey respondents highlighted challenges and benefits associated with on-site and off-site TFC methods. Approximately 28% of professionals identified longer build times as a significant issue associated with on-site construction. A further 27% raised concerns regarding weather-related delays, material wastage, and inconsistent build quality, factors often linked to site-dependent variability and manual errors. These challenges were commonly perceived to undermine schedule certainty and long-term performance, especially in projects exposed to Scotland's unpredictable weather conditions.

In contrast, off-site prefabrication methods were positively viewed by a large proportion of participants, with over 75% indicating that off-site methods provide better control over quality, reduce site disruption, and improve overall construction safety. In particular, over 65% of respondents noted the efficiency of prefabrication, especially the speed of on-site assembly and ease of coordination among trades. However, nearly 32% of professionals expressed reservations about off-site techniques, particularly concerning logistical constraints (e.g. transporting large components to remote sites), higher upfront capital costs, and limited design flexibility once the manufacturing process is underway.

Despite these limitations, many favoured off-site TFC for its sustainability advantages, reduced waste, and enhanced ability to meet performance standards such as airtightness and thermal insulation. A notable 45% of respondents mentioned faster project delivery as a critical benefit of off-site methods, especially when integrated with advanced planning and digital coordination.

Overall, the findings revealed that while off-site construction offers considerable benefits in quality, safety, and sustainability, its success depends on careful early-stage planning and efficient logistics. Meanwhile, on-site construction remains valuable in contexts where adaptability, traditional craftsmanship, or low capital cost is prioritised. Based on the questionnaire responses, approximately 2% of participants explicitly advocated for hybrid solutions, referring to the benefits of combining on-site and off-site construction methods to suit project-specific requirements.

4.1.6 Addressing the Housing Shortage

According to the survey, approximately 60% of respondents identified off-site prefabrication including timber frame, modular systems, and closed panel construction as the most suitable solution to address the UK's housing shortage. These methods were complimented for their scalability, potential for mass production, and capacity to accelerate housing delivery while maintaining quality standards. Specific comments noted the advantages of decentralised production and faster on-site assembly, which could significantly reduce programme durations and ease pressure on skilled labour availability.

Despite this preference, around 10% of participants suggested a hybrid approach, combining off-site efficiency with the flexibility of traditional construction methods, particularly in rural or logistically complex sites. Additionally, 18% of responses reflected uncertainty or emphasised non-technical solutions, such as government

investment, policy reform, and increased funding for affordable housing as necessary complementary strategies.

Furthermore, several professionals highlighted a persisting barrier in public perception, noting that some potential occupants remain hesitant to adopt modern prefabricated homes, often due to concerns around appearance, robustness, or resale value. This highlights the need for education, marketing, and policy alignment to build confidence in modern construction techniques as viable long-term housing solutions.

4.2 INTERVIEW FINDINGS

To complement the survey data, interviews were conducted with two site managers from a major UK housing developer with over six decades of experience in TFC. Their insights provided practical perspectives on construction efficiency, sustainability, cost management, and quality control in the Scottish housing sector.

Both interviewees emphasised the efficiency of TFC in Scotland's variable climate. Interviewee I stated that *"using open-panel timber kits constructed by our sister company allows internal work to start immediately once the building is wind and watertight,"* offering a clear advantage over off-site systems or double-block masonry which require longer lead times. Similarly, Interviewee II highlighted that "*pre-assembled kits help maintain progress even in poor weather*," thereby reducing delays and keeping projects on schedule.

Sustainability was described as a key consideration in construction decisions. Both managers noted efforts to reduce environmental impact using recycled materials, energy-efficient products, and strict waste management. Interviewee I explained, "*we install energy-efficient systems and enforce waste policies to encourage recycling*," while Interviewee II added, "*these practices significantly reduce our carbon footprint and promote greener construction*."

Cost and time management were also central themes. While acknowledging slightly higher upfront costs, Interviewee I observed that "*faster build times balance the expense, leading to more handovers and improved efficiency*." Interviewee II echoed this view, noting that "*balancing affordability and high standards is essential for successful delivery*."

Quality control was rigorously enforced through inspections by internal teams, building control, and National House Building Council (NHBC) regulators. Both interviewees described structured quality procedures. Interviewee I noted, "*we use photographic records, regular toolbox talks, and detailed snagging inspections by senior management*," while Interviewee II stressed that *"ongoing supervision and compliance checks ensure the final product is safe, durable, and built to last."* Overall, the interviews reinforced the view that TFC especially when supported by integrated supply chains and experienced site teams offers a practical, efficient, and quality-focused approach suited to the demands of the modern UK housing sector.

5. DISCUSSIONS

5.1 SUSTAINABILITY

Sustainability continues to be a defining objective in construction, particularly as the built environment seeks to align with global carbon reduction goals. Both on-site and off-site TFC methods offer environmental benefits. Off-site prefabrication is frequently perceived as more sustainable due to controlled production and minimised waste. According to Hart et al. (2019), timber construction prevents approximately 3.9 tonnes of CO_2 emissions per tonne of wood used, reinforcing the environmental advantages of timber-based systems.

Survey findings show that approximately 75% of respondents believed off-site construction contributed positively to sustainability due to reduced site waste and lower emissions from fewer deliveries. However, respondents also pointed out that prefabricated systems often require additional materials (e.g., extra OSB sheathing and polyurethane insulation), which may offset some environmental gains. Conversely, on-site TFC allows for using locally sourced materials and mineral wool insulation, which is perceived as more environmentally friendly, echoing conclusions drawn by Nikologianni et al. (2022), who advocate for place-based sustainability practices.

Interview insights further support this dual perspective; both participants highlighted the importance of energy efficiency and material sustainability, regardless of the method used. Ultimately, deciding which system is more sustainable appears to depend on contextual factors such as material sourcing, transportation logistics, and climatic conditions.

5.2 COST

Cost is a major consideration influencing strategic procurement and operational decision-making in construction. While prefabrication offers long-term savings, especially in large-scale developments due to its efficiency and repeatability, initial investment remains a barrier. Shahzad et al. (2015) assert that off-site construction can reduce life-cycle costs, particularly in mass housing projects.

In the present study, 44% of respondents recognised off-site prefabrication as a cost-effective option. However, challenges persist that limit local manufacturers in northern regions of Scotland, resulting in higher transport costs and often making traditional on-site construction more viable in remote areas. Interview data reinforced this nuance; large developers prioritise cost control and economies of scale, whereas smaller firms often opt for customisation, even if it comes at a higher price.

5.3 TIME

Time efficiency is another pivotal factor in construction delivery. Off-site prefabrication is credited for significantly reducing on-site construction time. Hashemi (2013) supports this by noting that timber frame systems require fewer person-hours than masonry construction. About one-third of survey respondents cited time savings as a key advantage of off-site prefabrication.

However, off-site prefabrication is not without its time-related challenges. Respondents highlighted long lead times, manufacturing bottlenecks, and the need for specialised equipment such as cranes. Moreover, limited local expertise in some regions slows the

adoption of these systems. Traditional TFC, by contrast, allows immediate site mobilisation post-approval and is often favoured for projects requiring greater adaptability. Interview responses echoed this sentiment, emphasising that while prefabrication speeds up certain phases, the overall benefit hinges on precise coordination and upfront planning.

5.4 QUALITY CONTROL

Quality control remains crucial for project success. Survey data showed 80% favoured prefabrication due to factory environments reducing variability and errors (Frühwald Hansson, 2011). However, concerns existed about insulation shifting and moisture ingress during transport (Mjörnell & Olsson, 2019). Interviews suggested that on-site methods, such as inspections, digital records, and skilled oversight, could match prefabrication quality. Off-site methods excel in precision and consistency, while on-site approaches offer flexibility for complex projects. Urban developers may prefer off-site for efficiency, whereas rural projects benefit from on-site adaptability. Policymakers should support logistics and training for off-site adoption, and educational bodies should align curricula with Modern Methods of Construction.

Several limitations should be acknowledged. Firstly, the limited qualitative sample (two interviews) restricts generalisability; future research should include more diverse experts for richer insights. Secondly, quantitative analysis was mainly descriptive due to the exploratory design and modest sample size (n=100). Although reliability was confirmed, future studies should employ advanced statistical methods for stronger validation.

6. CONCLUSIONS

This study evaluated on-site versus off-site TFC methods for low-rise housing in Scotland. Using quantitative data from 100 professionals and qualitative insights from industry interviews, the findings highlighted distinct method-specific advantages influenced by location, scale, and logistics. Off-site methods offered superior quality control, efficiency, and reduced waste but were constrained by higher initial costs and logistical complexities. Conversely, on-site methods were preferred for cost-effectiveness, adaptability, and reduced transport impacts in rural contexts. The key theoretical contribution addresses how contextual factors such as geographic, economic, and logistical factors influence TFC method selection and effectiveness. Practically, the study guides policymakers and developers in strategically aligning construction methods with Scotland's housing targets, recommending targeted investment to overcome barriers to off-site adoption. Ultimately, a hybrid approach, integrating the strengths of both methods, could maximise overall effectiveness. Future research should broaden the geographic scope and explore commercial sector applications to enhance sustainability and efficiency further.

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