Key Determinants of Offsite Construction Innovation in Zimbabwe's Steel Fabrication and Erection Sector

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Abstract

The researcher sought to establish key determinants of offsite construction (OSC) innovation within Zimbabwe's steel fabrication and erection sector. The study, motivated by the lethargic adoption of offsite construction innovation techniques and limited context-specific evidence regarding the exact determinants of offsite construction innovation in the sector, adopted a qualitative exploratory methodology to achieve its objective. It leveraged findings from key informant interviews and focus group discussions supported by secondary data. The study participants were composed of twenty-one construction sector artisans. The findings revealed the confluence of five interrelated factors, including necessity, regulatory pressure, market demand, quality and ecological efficiency, that collectively shaped the adoption and diffusion of OSC technologies in the country. A primary catalyst emerged as a necessity as firms responded adaptively to systemic constraints such as the COVID-19 pandemic, rapid urbanisation, economic volatility and an expanding housing deficit. The results indicated that pandemic-induced disruptions compelled construction companies to explore modular and prefabricated systems as faster, safer and more cost-effective alternatives to conventional methods of innovation. Regulatory pressure was identified as a key driver, with environmental and policy frameworks including the Environmental Management Act and the National Development Strategy 1 (2021–2025), encouraging sustainable and quality-driven practices. Further, evolving market demand was recognised as a significant driver, as clients increasingly prioritise speed, aesthetics and cost predictability while firms utilising OSC methods achieved market differentiation through enhanced quality assurance, precision and flexibility, consistent with Porter's (1990) Competitive Advantage Theory. The study concluded that the convergence of necessity, regulatory evolution and market sophistication has repositioned Zimbabwe's steel construction sector toward industrialised and sustainable innovation models. The findings underscored the transformative potential of offsite construction as a viable pathway for resilience, efficiency and competitiveness within the broader context of Zimbabwe's Vision 2030 and the United Nations Sustainable Development Goals (SDGs).

Keywords: Offsite innovation, construction, drivers

Introduction

The construction sector significantly contributes to global environmental degradation, given its dependence on orthodox and resource-intensive practices. Principally, carbon-intensive traditional brownfield on-site construction techniques position the sector as a key climate change driver (Ugochukwu-Chioma, 2015). The sector's growing ecological impact justifies the urgency of social, structural and economic transformations that align with the United Nations Sustainable Development Goals (SDGs) (Elhacham et al., 2020).

Background to the study

Construction innovation, primarily steel-based offsite construction (OSC), offers a critical pathway for enhanced sustainability, productivity and sector competitiveness (De Vasconcelos, Cândido & Heineck, 2020; Loosemore, 2015). OSC is rooted in prefabrication and preassembly of building components within controlled environments, which is then followed by onsite assembly (Gibbs, 2019). The process supports construction timelines, superior quality, minimal resource (water and energy) utilisation and improved environmental performance (Ho et al., 2018; Akintoye et al., 2012). Within the framework of the Fourth Industrial Revolution (4IR), digital technologies, as well as smart materials and automation, have further bolstered offsite construction, resulting in transformational urban infrastructure potential and smart city development (Matamanda et al., 2022; Ojo-Fafore et al., 2021).

Extensive benefits that include cost savings, time efficiency, structural resilience, improved building performance and design flexibility, drive offsite construction adoption (Hum, Chong, & Wang, 2020; Wuni & Shen, 2019; Ferdous et al., 2019; Lacey et al., 2018; Park et al., 2016). Most scholars contend that urgent socio-economic pressures, including population growth, rapid urbanisation and housing deficits, have compelled construction firms to embrace efficient building techniques (House of Lords, 2018; De'ath & Farmer, 2020). The recent COVID-19 pandemic has further illustrated the need for offsite construction innovation, given the need for rapid delivery of essential facilities, including hospitals, while concurrently mitigating workforce disruptions (Nguyen et al., 2023; Lin & Matt, 2020).

Offsite construction methods significantly reduce project timelines by between 30% and 70% (Alderton, 2019; Wong, Zwar, & Gharaie, 2017), enhance project predictability (Shibin, Gunasekaran & Dubey, 2017) and minimise weather-related delays (Wing et al., 2017). Such efficiencies have resulted in faster returns on investment while decreasing operational risks and this makes necessity-driven adoption particularly relevant in addressing urban infrastructure challenges and housing deficits globally (Jiang et al., 2017; McKinsey Global Institute, 2017).

Government policy and regulatory instruments have additionally been critical in fostering OSC adoption. Studies indicate the positive influence of revised legal frameworks, building codes, permits and adoption incentives on adoption rates (Burgess et al., 2020; CITB, 2017; Building Better Building Beautiful Commission, 2020). In Singapore, Sweden and China, for instance, higher OSC adoption rates coincide with stronger regulatory support (Burgess, Jones, & Muir, 2018; UN, 2018; Burgess et al., 2020). It is noted that regulatory drivers enhance quality performance, considering that mandatory prototype testing, quality control and pilot deployments guarantee high-quality consequences and diminish defects (Teng et al., 2017; Rukuvia et al., 2022; Arif et al., 2017).

The centrality of market demand in driving offsite construction adoption based on factors such as changing client preferences, urban housing needs and increasing demand for sustainable buildings is empirically evident (Farmer, 2016; De'ath & Farmer, 2020). Growing ecological consciousness and rapid urbanisation have driven demand for green buildings, compelling construction firms to be innovative (Veselovska, 2017; Farmer, 2016; De'ath & Farmer, 2020). Contractor competition is also an important market driver for OSC adoption, enabling firms to deliver cost-effective, high-quality and timely projects, improving constructability, flexibility and operational efficiency (Fish, 2019; House of Lords, 2018; OHS, 2018). Construction firms that have adopted offsite construction have achieved standardised processes, modularisation and automation, which constitute significant sources of firm competitive advantage.
However, several constraints, including cultural conservatism, interoperability challenges, high costs, skills deficits and limited policy, impair the global OSC adoption (Ortega, Mersa, & Arlacon, 2023; Liu et al., 2023; Agapiou, 2022). The barriers correspond with the Transaction Cost Theory, contending that hidden coordination, negotiation and compliance costs deter innovation adoption (Li, Arditi, & Wang, 2014).

The construction sector in Zimbabwe is a critical economic growth, employment and infrastructure development driver contributing 2.9% of the GDP in 2014 (Nyoni & Bonga, 2016). Nonetheless, structural inhibitions, including the dependence on brownfield construction practices, a two-million housing deficit and climate change vulnerability, have hindered the sector's performance (Ministry of Housing and National Amenities, 2023; Meteorological Services Department, 2023; ZIMSTATS, 2022). Initiatives, including the economic blueprint ZIMASSET, Vision 2030 and Infrastructure Development Bank of Zimbabwe (IDBZ)-led projects, demonstrate the country's trajectory towards innovation, but slow implementation and archaic legal frameworks impair offsite innovation adoption in Zimbabwe's construction sector (IDBZ, 2023; Chigudu, 2021).

The challenge of slow implementation is compounded by the dominance of current studies grounded on Western contexts (Ferdous et al., 2019; Larcey et al., 2018; Zuo and Zha, 2017; Park et al., 2016), which in turn fail to adequately capture the institutional, socio-economic and industrial realities that are specific to Zimbabwe. Consequently, limited empirical evidence exists that explains what drives OSC innovation in the country's steel fabrication sector.

Statement of the problem

There is a dearth in context-specific knowledge which forestalls the development of targeted strategies to promote OSC adoption and improve sector performance. This underlines the critical need to investigate the key determinants of off-site construction innovation in Zimbabwe, with particular focus on how necessity, regulatory frameworks and market demand shape innovation within the steel fabrication and erection sector.

Significance of the study

This study significantly contributes to the body of knowledge regarding offsite construction adoption in Zimbabwe's construction sector, characterised by limited empirical evidence. The study's findings on what drives offsite construction adoption offer practical guidance for policy, regulation and industry decision-making. They can help improve planning, resource use and sustainability in construction, while supporting Zimbabwe's Vision 2030 goal of reaching upper-middle-income status and SDG 9's focus on resilient infrastructure and innovation.

Review of related literature

In terms of the theoretical framework, the Technology Acceptance Model (TAM), attributed to Davies (1986) underpins the current study. It contends that two specific variables determine an adopter's attitude towards new technologies and these are (1) perceived usefulness and (2) perceived ease of use of such technologies. The model suggests that technologies are more likely to be adopted when users feel that the technology will enhance their job performance, especially if such technologies contribute to self-efficacy and instrumentality of the users (Davies, 1986). It further adds that such technologies are more likely to be adopted when their adoption is free from effort, as to allow the user extra time to engage in other activities related to their work (Sakala and Phiri, 2019). In line with the above discussion of the Technological Acceptance Model, this researcher was interested in the acceptance of offsite construction technology by the local construction institutions in Zimbabwe. The study was particularly interested in stakeholder perceptions of such construction innovations within the context of offsite steel-based construction projects in Zimbabwe. The model applied to the current study in that the perceived usefulness construct could help in explaining how stakeholder perceptions of the benefits of offsite construction could influence their intention to adopt. In addition, the perceived ease of use construct could help explain how stakeholders' perceptions of ease of use of offsite construction innovation could influence their intention to adopt. Thus, if construction sector stakeholders perceived offsite construction technologies to be easy to use and implement, this could influence their adoption of such practices. The TAM could also be further extended to include contextual factors specific to Zimbabwe's construction sector

The review of literature on stakeholder perception of offsite construction innovation identifies a complex set of interrelated drivers that either stimulate or hinder their adoption across diverse contexts. A significant number of scholars noted the centrality of time performance drivers in influencing offsite construction innovation elsewhere. In a systematic literature review, Wuni et al. (2023) note that, generally, the construction sector is supposed to achieve a competitive advantage based on project delivery within agreed timelines.

Related studies also alluded to cost-performance drivers of offsite innovation. Often, construction projects have experienced cost overruns leading to stakeholder conflict (engineers, project consultants, construction crew and clients), especially in the context of onsite construction modalities (Jiang et al., 2017). McKinsey Global Institute (2017) confirms that on a global scale, most construction firms are failing to meet their budgetary allocations and some large-scale projects have gone 80% above budget. Jiang et al. (2017) note that most conventional construction projects are performing below the required quality standards, often resulting in client dissatisfaction. Thus, the adoption of offsite innovation addresses the quality concerns in countries such as the UK given that offsite production occurs within controlled environments where there is room for redesign (Ozohron & Oral, 2017). Alderton (2019) contends that offsite construction has been noted to reduce construction time by between 30% and 70%, which fosters shorter payback periods and speedy returns on investment for construction projects. Thus, offsite construction innovation is associated with decreased programme time and certainty regarding the completion of given construction projects (Wong, Zwar & Gharaie, 2017). Cost performance drivers have been lumped together into reduced construction costs (Alderton, 2019); reduced labour costs (Wong et al., 2017); maximisation of returns (Švajlenka, Kozlovská & Spišáková, 2017); reduction in project life cycle costs (Yunus et al., 2017); reduction in demolition and deconstruction costs (Yunus & Young, 2016) and certainty of project costs (Ozohorn & Oral, 2017).

Literature on stakeholder perceptions of drivers of offsite innovation also points towards quality improvement drivers grouped into: ability to achieve high quality projects (Dancoz Garrido et al., 2023); improved project level quality control (Arif et al., 2017); improved design quality (Goh & Goh, 2019); improved life cycle performance (Hong et al., 2018); improved building integrity and improved aesthetic performance as well as supervision (Tanko et al., 2017); reduced snagging and defects (Steinhardt & Marnley, 2017); improved project consistency (Ogochukwu & Chioma, 2015) and presence of repetitive layouts especially in buildings like schools, hospitals and prisons.

The reviewed literature categorised the productivity drivers of offsite construction innovation into: improved site management activities (NHBC Foundation, 2020); lower project risk (Ilke Homes, 2020); increased component life (ONS, 2018); increased value for money (Milbank, 2019); reduced amount of onsite activities (Milbank, 2019; ONS, 2018Ilke Homes, 2020, House of Lords, 2018); better site operations (Royal Institute of Chartered Surveyors, 2018; Milbank, 2019); enhanced predictability and reliability (ONS, 2018); ease of application of lean principles (House of Commons, 2019a) and reduced need for manpower (House of Lords, 2018).

Sanchoz- Garrido et al., (2023), who note that the pursuit of sustainability initiatives, alternative energies and lifestyle changes has promoted a shift towards modern methods of construction premised on the adoption of Industry 4.0 technologies. Dosumu and Aigbovba (2018) note that economic factors that encompass cost efficiency, project affordability and environmental and social considerations related to clean air supply drive offsite construction innovation. Equally, Sutrisna, Leong, Hamad and Zaman (2023) opine that the rapid depletion of natural resources due to traditional onsite construction techniques spurred the adoption of offsite innovation in Australia. The literature on the sustainability drivers of offsite innovation indicates that collectively, offsite innovation is associated with reduced construction dust (Housing Today, 2020); reduced construction noise (House of Lords, 2018); improvement in the health and safety of construction employees (House of Commons, 2019a); improvement in employee working conditions and job security (HM Government, 2020); lower footprint in relation to construction materials (HM Government 2018a); waste reduction (HM Government 2018); decrease in community disturbance (Ilke Homes, 2020); improved energy efficiency (Ilke Homes, 2020); reduced construction water footprint (Milbank, 2019); reduction in site disruptions (House of Lords, 2018); lower embodied carbon emissions (House of Commons, 2019a); achievement of sustainable competitiveness (NHBC Foundation, 2019) and the demonstration of corporate social responsibility (Housing Today, 2020). In view of these motivating factors (drivers), it is imperative to establish the prevalent factors that influence the adoption of offsite construction innovation in Zimbabwe's construction sector.

Research Methodology

In fulfilling the study objectives, the researcher embraced the interpretivism philosophy, which meant to interpret the lived experiences of stakeholders by focusing on language and shared meanings based upon a social approach to knowledge development. The researcher, therefore, realised the futility of reducing the complex phenomenon of offsite construction innovation into rigid laws like generalisations commonly associated with positivist philosophies. The study also adopted a qualitative paradigm in its quest to capture the nuanced and context specific stakeholder insights regarding the determinants of offsite construction innovation adoption in the steel fabrication and erection sector in Zimbabwe. This was informed by the

imperfect nature of knowledge regarding the exact determinants of offsite construction innovation in Harare, Zimbabwe. This also explained the decision to adopt the inductive (theory-building) approach, premised on a phenomenology strategy through which the researcher targeted the lived participant experiences of offsite construction innovation. The study targeted a population of construction executives, professionals and senior managers, because of their vanguard role in offsite construction innovation in the sector. The study embraced purposive sampling in identifying the participants, consisting of builders, engineers, architects, construction supervisors, quality controllers and business owners to ensure representation across the design, construction, supervision and quality control roles. The data was collected through in-depth interviews targeting key informants, focus group discussions targeted at builders, architects and business owners and mixed participant and non-participant observations as well as document analysis. The researcher also ensured academic rigour through embracing member checking, prolonged engagement, triangulation, thick descriptions and trust building. The collected data were in turn analysed through thematic analysis based on Braun and Clarke's (2006) six-stage approach. In addition, ethicality was achieved through adopting informed consent, confidentiality and non-malfeasance towards the research participants.

Data Presentation

The participants' ages ranged from twenty-five to sixty-two years and they were predominantly male (81%), with extensive sector experience (>fifteen years). Education levels ranged from O Levels to master's degrees, warranting credible insights. See Table 1 below for participant biodata.

Table 1: Participant Biodata

Interview participant Code	Age (years)	Sex (Male/ Female)	Highest level of education	Work experience	Designation
Lisa Mhungu KI01	25	F	Engineering Degree	Below 5 years	Structural engineer
Bright Fadi KI02	62	M	Engineering Degree	Over 15 years	Rigger
Keith Pande KI03	50	M	Software Engineer Degree	Over 15 years	Draughtsman
Melusi Baya KI04	45	M	Quantity Surveyor Diploma	Over 15 years	Quantity surveyor
Tim Ndenga KI05	58	M	Welding & Rigging Diploma	Over 15 years	Construction supervisor
Chenge Pote KI06	52	M	Construction Management Degree	Over 15 years	Gang leader
Ralph Riggs KI07	40	M	Electrical Engineering Master's degree	Over 15 years	Electrical engineer
Sean Briggs KI08	49	M	Quality Assurance Master's degree	Over 15 years	Quality controller
Tendai Jerin KI09	29	M	Structural Engineering Master's degree	Over 15 years	Structural engineer

Betty Yosa KI10	54	F	Civil Engineering Degree	Over 15 years	Draughtsman
Jerry Nkala KI11	37	M	Fabrication & Rigging Diploma	11- 15 year	Rigger
Tapiwa Meki KI12	59	M	Electrical Engineering Degree	Below 5 years	Electrical engineer
Hebert White KI13	62	M	Bricklaying certificate	6 to 10 years	Builder
Don Kirate KI14	55	M	Architectural Engineering Master's degree	Over 15 years	Architect
Jestina Teki KI15	42	F	Diploma in Architect	Over 15 years	Architect
Tim Moya KI16	28	M	Architectural master's degree	Over 15 years	Architect
Chen Yung KI17	44	M	Diploma in Woodwork & Joinery	Over 15 years	Carpenter
Rudo Ganda KI18	42	F	Project Management Degree	Over 15 years	Construction supervisor
Isaac Chune KI19	37	M	Civil Engineering Degree	Over 15 years	Construction supervisor
Chari Meki KI20	39	M	Diploma in Carpentry Studies	11-15 years	Carpenter
Pen Wang KI21	57	M	Electrical Engineering Degree	Below 5 years	Electrical engineer

Source: Primary data (2025)

Data were generated through semi-structured interviews reaching a point of data saturation at twenty-one key informants, representing a diverse professional cross-section of Zimbabwe's steel fabrication and erection sector. The participants' roles spanned the offsite construction value chain, including design and planning, construction and installation, supervision and management and quality control for rich and triangulated insights into innovation dynamics. Most respondents were experienced professionals who provided credible and industry grounded perspectives. Individuals aged above forty years (67%) dominated the participant pool, highlighting the sector's mature workforce. Gender distribution revealed a male dominated industry (81% male, 19% female), reflecting insistent structural barriers to women's participation in technical roles. Educationally, the majority held tertiary qualifications, with 57% possessing undergraduate degrees and 24% master's degrees, confirming a knowledgeable participant base capable of informed technical analysis. In terms of experience, 71% had over fifteen years in the sector, reinforcing the reliability of their contributions.
Professionally, participants straddled various construction clusters encompassing Design and Planning (35%), Construction and Installation (35%), Supervision and Management (30%), thereby capturing all critical stages of the offsite construction process. Overall, the participant profile reflects a mature, skilled and multidisciplinary group whose collective expertise provided robust and contextually grounded insights into stakeholder perceptions of offsite construction innovation in Zimbabwe's steel fabrication and erection sector.

Complementary data were obtained from focus group discussions (FGDs) with seventeen cross-industry participants, including business owners and architects, to capture group dynamics and consensus as well as collective perspectives on perceived drivers of offsite construction innovation in Zimbabwe's steel fabrication and erections sector.

Table 2: Characteristics of Focus Group Discussion participants

Participant	Sex (M, F)	Age group	Highest level of education	Work experience (years)	Designation
John Mutape - BO1	M	Over 40 years	Business Management Degree	Over 15	Business Owner
Pume Radhebe - BO2	M	Over 40 years	Economics Degree	Over 15	Business Owner
Clara Makone - BO3	F	Over 40 years	Accounting Degree	Over 15	Business Owner
Jane Smith - BO4	F	Over 40 years	Construction Management Degree	Over 15	Business Owner
Faith Munje - BO5	F	Over 40 years	Quantity Surveying Diploma	Over 15	Business Owner
Trish Tigere - BO6	F	Over 40 years	Diploma in Construction Technology	Over 15	Business Owner
Yolanda Muguta - BO7	F	Over 40 years	Diploma in Quantity Surveying	Over 15	Business Owner
Talent Gwambe - BO8	F	Over 40 years	Diploma in architectural engineering	Over 15	Business Owner
Ronald Laing - ARCH1	M	Over 40 years	Architecture Degree	Over 15 years	Architect
Ryan Timbe - ARCH2	M	Over 40 years	Architecture Degree	Over 15 years	Architect
Mashoko Gomo - ARCH3	M	Over 40 years	Architecture Degree	Over 15 years	Architect
Ting Chung - ARCH4	M	Over 40 years	Architecture Degree	Over 15 years	Architect
Rob Ward - ARCH5	M	Over 40 years	Architecture Degree	Over 15 years	Architect
Dennis Paduri - ARCH6	M	Over 40 years	Architecture Degree	Over 15 years	Architect
Blessing Goto - ARCH7	M	Over 40 years	Architecture Degree	Over 15 years	Architect
Chris Jumbe - ARCH8	M	Over 40 years	Architecture Degree	Over 15 years	Architect
Edna Kasawaya - ARCH9	F	31 to 40 years	Architecture Degree	6-10 years	Architect

Source: Researcher (2025)

The demographic data in Table 4.2 demonstrates that age-wise, most participants (94%) were over forty years of age while only 6% were between thirty-one and forty years. Regarding gender distribution, there were more males (59%) compared to females (41%), further confirming earlier observations of the gendered nature of the offsite construction sector in Zimbabwe. In terms of education, most 76% had university degrees while 24% had diplomas.

In terms of work experience, most (94%) had over fifteen years' experience, while only 6% had between 6 and 10 years. This shows that the study results emanated from participants with extensive experience, considering their roles as business owners and senior artisans in the steel fabrication and erection sector in Zimbabwe. The FGDs consisted of Business Owners (47%) and Architects (53%). The researcher capitalised on major events that brought the participants together, as in the case of winter schools for the architects and morning briefings for construction crews, including architects, to conduct the FGDs.

The study also leveraged non-participant observation at OSC sites to document practices, behaviours and physical settings to complement primary data. In addition, secondary data sources, including industry reports, policy documents and corporate records, fostered methodological triangulation and promoted contextual understanding of the study area.

The generated information from interviews and FGDs was then transcribed, coded and thematically analysed using manual analysis targeting the frequency and relevance of recurrent themes. Thus, thematic analysis emphasised the identification of drivers and the findings were presented using narratives and verbatim quotes for rich and context-sensitive interpretation. To achieve trustworthiness, the study adopted member checking, triangulation, prolonged engagement and ethical rigor based on voluntary participation, informed consent, confidentiality and anonymity. Member checking involved respondent or participant validation of the accuracy of captured data, while triangulation involved the combination of data sources and instruments for cross-reference purposes. In addition, prolonged engagement entailed spending considerable amounts of time in the field to clearly understand participant experiences. Ethical rigour involved the embrace of varied ethical considerations in conducting the study, including informed consent, confidentiality and non-malfeasance.

The researcher embraced a hybrid insider-outsider perspective in trying to understand the determinants of offsite construction innovation. The insider perspective required the researcher to be part of, as well as being closely familiar with, the construction industry for a contextual understanding of offsite construction innovation in the sector. This insider perspective occurred because the researcher is part of the construction sector and this positionality allows for access to authentic data and interpretive depth. The outsider perspective required the researcher to maintain objectivity and distance, adding value through ensuring critical detachment and reduction in bias. The researcher was, therefore, able to offer objective analysis and minimise overfamiliarity bias and avoid taking-for-granted assumptions in the industry. The challenge, however, is that outsider perspectives often imply misinterpretation of localised nuances and heavy reliance on secondary data as opposed to industrial realities. This justified the need to embrace reflexive balance, allowing the researcher to deeply engage with the participants based on an insider role while concurrently maintaining analytical distance during the interpretation.

Results and discussion

This section presents the results of the study regarding the major drivers of offsite construction innovation within Zimbabwe's steel fabrication and erection sector. The results are categorised into three broad themes, including necessity, regulatory pressure and market demand and for each theme, the study first presented participant perceptions, followed by interpretive analysis supported by relevant scholarly literature. See Table 3 for a summary of the results.

Table 3: Themes and sub themes on determinants of offsite construction innovation

Theme	Sub-Theme	Source
14. Necessity	e. Cost efficiency f. Speed g. COVID-19 h. Population growth	Interviews, FGD, observation, document analysis
15. Regulatory pressure	c. Policy alignment d. Compliance standards	Interviews, FGD, observation, document analysis
16. Market demand	d. Client preferences e. Competition f. Reputation	Interviews, FGD, observation, document analysis
17. Quality	d. Quality control e. Precision f. Building performance	Interviews, FGD, observation, document analysis
18. Eco-efficiency	c. Reduced waste d. Energy efficiency in design	Interviews, FGD, observation, document analysis

Source: Primary data (2025)

Necessity

The first theme 'necessity' reflected that it remained a pertinent catalyst for offsite construction innovation in the steel fabrication and erection sector in Zimbabwe. Such necessity emanated from contextual pressures encompassing the novel COVID-19 pandemic, rapid urbanisation, housing deficits and persistent economic instability. The participant sentiments indicated the effect of these factors in forcing construction forms to reimagine orthodox construction practices and embrace offsite construction innovation systems for faster, cost-effective and resilient construction outcomes. This was evident in the following participant quotes.

"COVID-19 changed the way we think about building. During lockdowns, we had to look for faster and safer ways to continue construction that is when modular and offsite systems proved very useful" (KI-07)

"With the kind of housing shortage in Harare, traditional methods are simply too slow and we had to start exploring offsite systems to deliver projects on time and reduce congestion on sites" (FGD-03)

"In this economic environment, every day saved is money saved. Offsite fabrication helps us meet deadlines, manage costs and still deliver good quality" (KI-14).

These results demonstrate the role of necessity-driven innovation in reflecting the industry's adaptive response to environmental and systemic constraints. The COVID-19 pandemic provided a critical turning point for the industry, indicating the limits of conventional and labour-intensive brownfield construction techniques. Thus, OSC offered opportunities for safe and faster construction alternatives, allowing for continuity of work under restricted movement conditions. These views support Assaad et al. (2022), who noted that modular construction proved a practical solution to maintenance of productivity during global crises.

Secondary data from the Zimbabwe Building Contractors' Association (ZBCA, 2021) supports

these accounts, claiming that construction output fell by over 30% in 2020 due to lockdown restrictions, but firms that adopted modular and prefabricated solutions reported quicker recovery and reduced project delays. The World Bank (2022) similarly noted that firms that embraced digitalisation and industrialised building systems accelerated post-pandemic recovery in Southern Africa. Theoretically, these findings affirm Schumpeter's theory of creative destruction, positing that innovation often arises from systemic disruptions that challenge established methods. In Zimbabwe, the intersection of public health emergencies and economic turbulence created a "necessity window" in which construction sector firms that embraced OSC achieved operational continuity and efficiency gains.

Rapid urbanisation in Harare also heightened the demand for rapid and scalable housing construction solutions. The ZIMSTAT (2023) indicates that Harare's population rose from one and a half million in 2015 to nearly two million in 2023 and this intensified pressure on the built environment. This finding resonates with Pheng and Hu (2019), who noted the role of urbanisation in compelling developing economies to innovate toward modular and industrialised construction systems that could meet mass housing needs. This corresponds with Rogers' (2003) Diffusion of Innovation Theory, which suggests that adoption accelerates when innovations solve pressing societal problems, as in the case of a housing crisis in Zimbabwe.

In addition, economic hardship has further reinforced the need for efficiency in construction cycles as the participant cited the role of economic volatility in compelling construction firms to strive towards cost predictability, shorter project cycles and resource optimisation. These views correspond with Alderton (2019) and Wong et al. (2017), who contend that offsite construction reduces labour costs, enhances productivity and ensures greater cost certainty. The Zimbabwe National Chamber of Commerce (ZNCC, 2022) reported that due to persistent currency volatility and supply chain disruptions, cost predictability has become a strategic priority. Collectively, the need to survive and remain competitive in a VUCA (volatile, uncertain, complex and ambiguous) economic context has transformed offsite innovation from a strategic choice into a functional imperative for Zimbabwe's construction industry.

Regulatory pressure

The study found that regulatory pressure is critical in shaping the course of offsite construction innovation in Zimbabwe's steel fabrication and erection sector. The participants described the compulsive effect of existing construction sector regulations on sectoral innovation and improved quality performance framework as evident in the following quotes.

"The construction sector has recently been under pressure from strict environment management regulations such as the [Environmental Management Act] EMA Act which punishes errant conduct towards the environment and encourages sustainable construction practices" (KI-16).

"So far, what I have seen is that the government is coming up with innovation hubs, which will go a long way in driving innovation in the industry as well, but we haven't realised the fruits for now but only in terms of importation of ready-made steel the government has allowed that to happen" (FGD-03)

"The Mount Hampden Smart City initiative shows the government's seriousness about sustainable and modern construction and this has motivated us to align our methods accordingly" (FGD-02).

These results suggest that environmental and policy-based regulations have reshaped Zimbabwe's construction landscape since environmental regulations, including the Environmental Management Act (Chapter 20:27), compel construction firms to adopt sustainable practices, pushing companies toward offsite fabrication to reduce site waste, emissions and ecological footprints. This corresponds with Thorpe et al. (2008), who identified environmental regulation as a powerful external driver of innovation, prompting construction firms to adopt sustainable technologies.

Similarly, the government initiatives have accelerated the impetus towards OSC adoption as participants referenced initiatives such as innovation hubs at universities, the Manhize Steel Plant and facilitation of steel imports as mechanisms that expanded access to modern materials and knowledge. The Zimbabwe National Human Settlements Policy (2022) openly advocates for the use of industrialised building systems (IBS) and modular construction to enhance quality, affordability and speed in housing delivery. This corresponds with the Zimbabwe National Development Strategy 1 (NDS1, 2021–2025), which identifies innovation and infrastructure modernisation as key enablers of economic growth.

These findings resonate with Thorpe et al. (2008), who emphasise that regulatory pressure often catalyses technological innovation in the construction sector. Moreover, Sanchez-Garrido et al. (2023) and Veselovska (2017) argue that quality-driven regulation reinforces precision manufacturing, enhancing overall product reliability. This demonstrates therefore that in Zimbabwe, the regulatory and policy frameworks have dual significance serving as compliance instruments, as developmental tools that nurture innovation, improve environmental performance and elevate construction quality.

Market demand

The participants also noted the role of change in market demand, encompassing evolving client expectations, competitive pressures and a growing appreciation for aesthetics and quality as pertinent OSC drivers. The participants observed that customers are increasingly seeking high quality, durable and visually appealing structures delivered within shorter timeframes and such trends have positioned offsite innovation as a competitive advantage generator for the construction sector. This was evident in the following quotes.

"Clients today are more demanding and they want beautiful finishes and quick delivery which offsite methods can offer" (KI-18).

"Competition is very high in our sector and if you are still relying only on traditional construction, you will lose clients to those offering faster and neater modular options." (FGD-01).

"The market is shifting as everyone wants efficiency and quality assurance which gives offsite innovation that edge." (KI-05).

These results suggested that the Zimbabwean construction market evolved in response to global and local consumer trends that prioritise speed, quality and design flexibility. Offsite construction satisfies these demands by enabling precision engineering, modular scalability and aesthetic uniformity in line with Teng et al. (2017), who posit that clients' pursuit of value, design efficiency and reliability drives market-oriented innovation in construction. This aligns

with Porter's (1990) Competitive Advantage Theory, asserting that firms innovate to create value differentiation and respond to consumer sophistication.

Secondary data further corroborated these trends according to the Confederation of Zimbabwe Industries (CZI, 2023), which noted that the local construction and steel fabrication market grew by 12% between 2021 and 2023, due to private sector investment in industrial parks, warehouses and commercial buildings that favour modular steel systems. Likewise, Knight Frank Zimbabwe (2023) reported a 15% demand surge for prefabricated industrial structures in Harare and Bulawayo due to lower construction turnaround times.

In addition, intense competition in the construction sector has also become a strategic differentiator among firms since companies that leverage modular and prefabricated techniques achieve first-mover advantages by reducing lead times and delivering higher-quality outcomes. The Zimbabwe Investment Development Agency (ZIDA, 2024) opines that foreign investment in steel and modular construction in Zimbabwe has increased by 18% since 2021, creating new benchmarks for quality and cost competitiveness.

McKinsey (2018) similarly observed that firms adopting offsite innovation realise greater profitability and market share through enhanced operational efficiency. Moreover, participants' emphasis on aesthetics and finish quality further reflected a cultural shift in Zimbabwe's construction market, in which clients increasingly associated steel-based modular structures with modernity, durability and status. Dancoz-Garrido et al. (2023) confirm that offsite construction enhances aesthetic precision and design consistency and clients value such attributes in both residential and commercial sectors. The results contend that market demand and competition jointly serve as dynamic forces that continually reinforce offsite innovation as a strategic response to customer expectations, driving the industry toward modernisation and sustained competitiveness.

Need for quality

Quality emerged as a central theme in participants' perceptions of offsite construction innovation determinants. Participants reported that offsite methods ensured consistent quality, accurate measurements and enhanced long-term building performance given controlled production environments, skilled execution and adherence to engineering specifications.

Some participants indicated that offsite modules are produced in controlled environments, reducing the margin of onsite errors and improving opportunities for quality monitoring as evident in the following quotes.

KI-04- "Offsite innovation allows for improvement in quality control considering that modules are produced in controlled environmental to reduce on-site errors."

KI-10- "I also think it's easy to run quality assurance when producing under one roof and it's easy to monitor quality indoors as opposed to externally."

The above shows a relationship with aspects of precision and accuracy, given seamless joints and connections leading to improved overall product quality, as the following shows.

KI-04- "… the outcome of the product is also precise in terms of seamless joints and connections."

Offsite innovation produces stronger quality structures, considering that the right materials are used and when the work is done by skilled artisans, as the following claims show.

KI-15- "There is also the aspect of quality in the sense that steel structures are of stronger quality when correct material is used."
The results, therefore, suggest that offsite construction innovation is associated with improved product quality and assurance, resulting in better construction outcomes. Considering that the products are made in controlled environments, companies could minimise construction errors for improved product quality.

Likewise, Matamanda et al (2022) concur that offsite construction innovation is also associated with better quality control while limiting onsite work relative to connections to services, foundation, groundwork and building finishes.

Need for ecological efficiency

Stakeholders also identified eco-efficiency as a significant prompt for offsite construction innovation considering its potential for waste reduction, energy efficiency and environmentally friendly practices. Some participants claimed that offsite innovation reduced the level of waste and improved the sustainability of construction projects. Precision in material estimation reduced excess materials and associated chaos, as evident in the following quote.

FGD-02- "Offsite innovation offers opportunities for precise material estimation hence we can say goodbye to excess materials and the chaos they are associated with."

Moreover, waste reduction occurred since construction occurs in a controlled environment, reducing scrap and optimising material usage as the following indicates.

KI-10- "Efficiency in manufacturing during offsite construction in controlled environments leads to less scrap and optimal material usage so it's a win-win situation."

This indicates that offsite innovation is environmentally friendly, minimising environmental degradation, preserving natural spaces and minimising the levels of emission and radioactivity as the following indicates.

KI-16- "The structures are also environmentally friendly as there is little to no destruction of the environment as in the case where cement is used and you don't need to clear more ground compared to using ground, so a lot of environmental space is left untouched. So, it's noble to continue using offsite innovation."

KI-06- "Ecologically friendly designs- They are also very safe when it comes to the health aspect and there are no emissions and radioactivity since these structures are checked prior to being released on the market."

These views resonate with efficiency gains and loss reduction, considering the in-situ nature of construction.

Simpeh and Smallhood (2018) contend that offsite construction innovation is associated with

significant environmental benefits such as waste minimisation through recycling, reuse and recovery of waste streams.

Conclusion and recommendations

Multiple factors, including necessity, regulation and market forces, drive offsite construction innovation in Zimbabwe's steel fabrication and erection sector. Necessity emerged as a reactive yet transformative driver in which crises such as COVID-19, urbanisation pressures and economic instability compelled construction firms to adopt offsite systems for efficiency, safety and resilience. Additionally, regulatory pressure played a dual role as both a compliance framework and an innovation enabler that fostered environmentally responsible and quality driven practices aligned with national policy visions. Finally, market demand represented a proactive force that sustained innovation, as clients increasingly valued quality, speed and aesthetic excellence, incentivising firms to integrate modular and prefabricated solutions in Zimbabwe's construction sector. The study demonstrated how OSC innovation in Zimbabwe reflects a contextually adaptive model of industrial transformation, characterised by crisis induced learning, policy-guided evolution and market-anchored modernisation. The convergence of forces signifies a shift from traditional and labour-intensive construction methods to industrialised and knowledge-based construction ecosystems in the country. The government of Zimbabwe was encouraged:

to strengthen and harmonise existing regulatory frameworks to explicitly incorporate offsite construction standards and guidelines.

to operationalise policy instruments, including the NDS1 and the Human Settlements Policy, through fiscal incentives, including tax rebates for firms investing in modular technologies and local steel manufacturing.

to expand its regulatory scope to include green certification for offsite and modular projects, promoting eco-friendly innovation.

to intensify support for university–industry collaboration for enhanced research, prototypin and skills development in OSC systems.

Construction firms should:

institutionalise innovation management frameworks to systematically evaluate, adopt and scale offsite methods.

develop marketing and client education strategies to increase awareness of the quality, efficiency and sustainability benefits of offsite systems.

The private sector should:

form consortia or clusters to share infrastructure, technology and knowledge, reducing the high entry cost of OSC adoption.

invest in digital tools such as Building Information Modelling (BIM), automated steel fabrication and modular design software to complement offsite processes.

Academic and training institutions, including technical colleges and universities, should:

integrate industrialised construction modules into engineering and architecture curricula to develop skilled human capital.

Incentivise innovation hubs to undertake applied research focusing on locally adapted modular technologies using indigenous materials.

Future research

While this study contributed to an understanding of OSC innovation drivers in Zimbabwe, several avenues for future research remain, including the need for quantitative validation in which future studies should employ statistical models to quantify the relative influence of necessity, regulation and market demand on OSC adoption. Future studies could also conduct a comparative regional analysis based on cross-country studies within Southern Africa to reveal contextual similarities and divergences in innovation pathways.

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