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RECONCEPTUALIZING A MODEL FOR LEAN CONSTRUCTION SUPPLY CHAIN

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ABSTRACT

The inefficiency of construction projects in Tanzania made popular cost overruns, extensive delays, reworks, defects and accidents, including resource waste within the construction supply chain. Although scholars have proposed diverse ways to combat supply chain problems, these efforts lack an integrated lean construction supply chain (LCSC) model. Given the persistent resource constraints characterizing the construction industry, this study reconceptualizes an LCSC model for deployment to drive out waste. A critical review of relevant literature was conducted to identify which lean supply chain model predominates in construction in order to develop an LCSC model that integrates lean construction tools and supply chain strategies that were found to proffer better solutions. The paper offers novel theoretical insights that lay a foundation for subsequent empirical and practical implications for LCSC efficiency.

KEYWORDS

Construction, Lean, Supply Chain, Model, Project

INTRODUCTION

Research on the application of supply chain management started first to be investigated in manufacturing industries (McSharry et al., 2023). Given its usefulness, studies on the framework have now taken its course on construction projects. Substantial studies have been carried out on the applicability of supply chain management for construction projects (Chauhan et al., 2022; Cigolini et al., 2022). Further, lean construction practices and principles are widely researched and reported in construction (Koskela et al., 2020; McSharry et al., 2023). Construction supply chain research has also integrated lean project delivery approaches (Le & Nguyen, 2023; Sarhan et al., 2018). Vigorous integration of lean and supply chain strategies can address construction project productivity and resource efficiency problems (Koskela et al., 2020; Le & Nguyen, 2023). However, most of these studies have only focused on applying lean principles, with little emphasis on integrated lean supply chain approaches (Sarhan et al., 2018). These two phenomenological approaches (i.e. construction supply chain and lean construction) have been constantly and distinctly deployed on their own merits.

While lean construction aims at meeting customer needs, continuous improvement, and resource waste minimization (Demirkesen & Bayhan, 2020; Meng, 2019), construction supply chain integration helps with commitment and communication to enhance synergy and co-value creation (Koskela et al., 2020; Le & Nguyen, 2023). Supply chain integration increases

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collaboration and networking of key actors (contractors, consultants, developers) aligned in project delivery (Ballard & Elfving, 2020; Le & Nguyen, 2023). This dyadic synergy is key for lean construction supply chain (LCSC) efficiency at both inter- and intra-organisational levels, which will benefit these LCSC actors. Various studies have been expedited to provide solutions to the current construction supply chain problems in various regions, both in traditional and other project delivery paths. For instance, prior studies were carried out to test the use of traditional construction supply chain to reduce delays because of pre-construction deficiencies in construction projects (Koskela et al., 2020; Meng, 2019).

Although the Architecture, Engineering and Construction (AEC) industry contributes an average of 11% to the GDP of Tanzania's economy (Kikwasi & Escalante, 2020), studies suggest that the development of the industry in Tanzania is hindered by various factors including time/cost overruns, inadequate productivity, insufficient professional knowledge capital, competencies, skills, innovation, building codes, and the industry's supply chain fragmentation (Kikwasi & Escalante, 2020; Kikwasi & Sospeter, 2023; Lello et al., 2023; Bajjou & Chafi, 2020). To address these deficiencies, a robust study is required. At the same time, an LCSC model is lacking in Tanzania. Such a model will also curb challenges related to defects, rework, waste, lack of a common base for project information, lack of standard work, lack of collaboration, and lack of teamwork (Kikwasi & Escalante, 2020; Kikwasi & Sospeter, 2023; Lello et al., 2023). This will contribute to improvements in the construction industry compared to traditional management methods (Koskela et al., 2020; Meng, 2019). Therefore, drawing on the lean and supply chain integration theories, this paper addresses the following research question: *What model will promote lean construction supply chains in Tanzania?*

AN OVERVIEW OF RELATED LITERATURE

Given the construction challenges stated above, this study contends that robust lean tools integration, supply chain integration, lean innovative capability, and stakeholder support (conducive industrial policies, building codes, standards and IT systems embedded within LCSC) can significantly address resource limitations, thus offering positive practical consequences and innovations (i.e. LCSC efficiency) in construction projects. Prior research also indicates that construction projects constitute only 62% of value-adding activities and 12% of support activities (Demirkesen & Bayhan, 2020). This suggests that non-value-adding activities still dominate most of the current project works. Although policy recommendations by experts (e.g. Kikwasi & Escalante, 2020; Kikwasi & Sospeter, 2023; Lello et al., 2023) have been issued recently, comprehensive research efforts to eliminate waste in construction (given the persistent resource limitation) have not been thoroughly carried out. In addition, studies that have empirically investigated the supply chain of projects delivered through lean tools (i.e. using an integrated LCSC model) are scanty (Le & Nguyen, 2023). As an integral part of a major PhD research project, this study reconceptualises an initial integrated LCSC model, which will be tested and validated for deployment basing on sample data from Tanzania's construction industry.

THEORETICAL CONSTRUCTS OF THE MODEL

Considering the nature of construction problems and their proximal effects, this subsection proposes the following study constructs based on lean and supply chain integration (SCI) theories to guide the proposed LCSC model (see Figure 1):

Resource limitation. Resource constraints (e.g. finance, human capital and other tangible assets, such as equipment and supplies) will continue to shape organisational dynamics and routines as resources continue to be scarce. Drawing insights from lean theory, the primary driver of efficient production in the construction industry is its efforts to synthesize and deploy variables for novel project undertakings (Johnson et al., 2023; Zimina & Pasquire, 2011). As stated earlier, "lean" refers to generating value for clients while using less resources (Drevland & Lohne, 2023; Mossman, 2018). It involves a set of principles, axioms, techniques, tools and ways of thinking (sub-theories) that, when combined and applied, can assist individuals and teams in enhancing the processes and systems in which they operate (Koskela et al., 2020; Mossman, 2018).

Supply chain integration. Based on the *SCI theory*, the study opines that robust internal and external supplier and customer integration (Li et al., 2022; Perdana et al., 2019) has potential to leverage supply chain problems inherent in the construction industry. It aims at eliminating traditional functional silos and integrating the functional departments of a company into a single entity in order to meet the requirements of customers at the lowest system-wide cost (Li et al., 2022; Perdana et al., 2019). SCI scholars (e.g. Lello et al., 2023; Li et al., 2022; Perdana et al., 2019) advocate that all the nodes in the network and innovation ecosystems, whether inside or outside the firm, should focus on communicating, exchanging and sharing key information at various sub-systems, activities, relationships and operations.

Lean tools integration**.** Lean tools in construction are viewed as techniques, methods and principles that when strategically deployed have the potential to address resource waste and efficiency challenges. These include: the Last Planner System (LPS), Building Information Models (BIM), Integrated Project Delivery (IPD), Target Value Design (TVD), Lean Project Delivery System (LPDS) model, Choosing by Advantages (CBA), Just in Time (JIT), and the like. Drawing insights from lean theory and the dynamic capability literature, this study contends that construction organisations which can develop dynamic capabilities in effectively and efficiently deploying lean tools, enhances them to integrate, construct, and reconstruct internal and external resources to cope with the fast-changing environment (Johnson et al., 2023; Li et al., 2022).

Lean innovative capability**.** Johnson et al. (2023) define Lean Innovation Capability (LIC) as “an organization’s ability to achieve sustainable innovation performance that meets core customer needs while constantly iterating offerings to validate and learn by continuous market feedback-all via the effective leveraging and mindful embracing of resource limitations” (p. 3). In this context, firms must innovate by developing new processes, organizational forms and business models to achieve differentiation (Li et al., 2022; Manda et al., 2023).

Stakeholder ecosystem support. Based on the supply chain integration and stakeholder resource-based view literature, firms can acquire sustainable competitive advantages by establishing sustainable relationships with key stakeholders (Li et al., 2022; Manda et al., 2023). This enables them not only to capitalize on supply chain resources, but also sail through multiple stakeholder limitations and needs. For instance, while strategic IT vendors can offer supporting technologies (such as BIM, AI, business-to-business (B2B) platforms, blockchain, machine learning, etc.), the government/regulatory institutions can provide valuable policies, professional fee tax incentives and building codes that aim at achieving LCSC efficiency.

Lean construction supply chain efficiency**.** Performance (of organisation or project) is a multi-faceted phenomenon which in general depicts the level of effectiveness and efficiency of previous acts (Lello et al., 2023). The traditional view of project or organisational performance, has been expanded to include the modern dimensions of environmental and societal performance pillars. Therefore, according to Lello et al. (2023), a company’s performance is assessed not only by its capacity to satisfy and keep customers, but also by demonstrating its level of profitability and sustainability. This study focuses on efficiency outcomes that entail making best use of available resources such as project capital/life cycle cost limits, equipment and time saving in project execution. Effectiveness (e.g. visually appealing facilities, etc.) and commercial aspects (the “absolute values” of business performance such as profitability, cash flow and market share, patent counts, etc.) are not the scope of this work.

METHODOLOGY

The conceptual paper is based on the preliminary literature review of lean and supply chain integration (SCI) theories. The conceptual framework developed is the preliminary stage of a major research project (doctoral study) expected to solve the challenges impeding LCSC efficiency experienced in construction operations. The keywords for the search included "lean" AND ("construct*" OR "construction" OR "building" OR "built environment" OR "civil engineering" OR "engineering") AND ("supply chain" or “supply chain integration” or “supply chain network*” or “supply chain collaboration” or “supply chain allianc*” or “supply chain coordination”) AND (“model*” or “framework”)”. The search was dominated by, but not limited to, Web of Science (WoS) and publications in the International Group of Lean Construction (IGLC) repository. The WoS is considered the most reputable peer-reviewed database, with science citation indexed journals. The IGLC database was selected due to its lean-focused research direction. While there were articles addressing global LCSC concerns, preference was made for articles relating to developing countries (emerging economies) as the study context is characterized more by them. Although an attempt was made to consider the latest articles, the retrieved articles ranged between 2000 and May 2023 based on the PRISMA[3] exclusion/inclusion criteria. Initial search resulted in 381 articles. After limiting to subject area and relevance (i.e. engineering & construction building technology), 49 articles were finally obtained from WoS. These were supplemented with additional relevant articles from the IGLC repository. Content analysis was employed to extract relevant information on which lean supply chain model predominates in construction that feeds into developing the conceptual LCSC model that addresses supply chain problems as shown in Figure 1.

RESULTS

This section presents the literature review results on various supply chain models that have been explored in LCSC research in order to identify a model that predominates in construction. This synthesis has broadened and deepened our understanding of how these lean efforts have contributed to the theoretical and empirical examination of the phenomenon. Further, unpacking the extent of exploration in this discourse will aid the development of an integrated LCSC model and increase our awareness of proposed solutions to Tanzanian supply chain problems that alleviate their effects and proffer guidelines on policy recommendations.

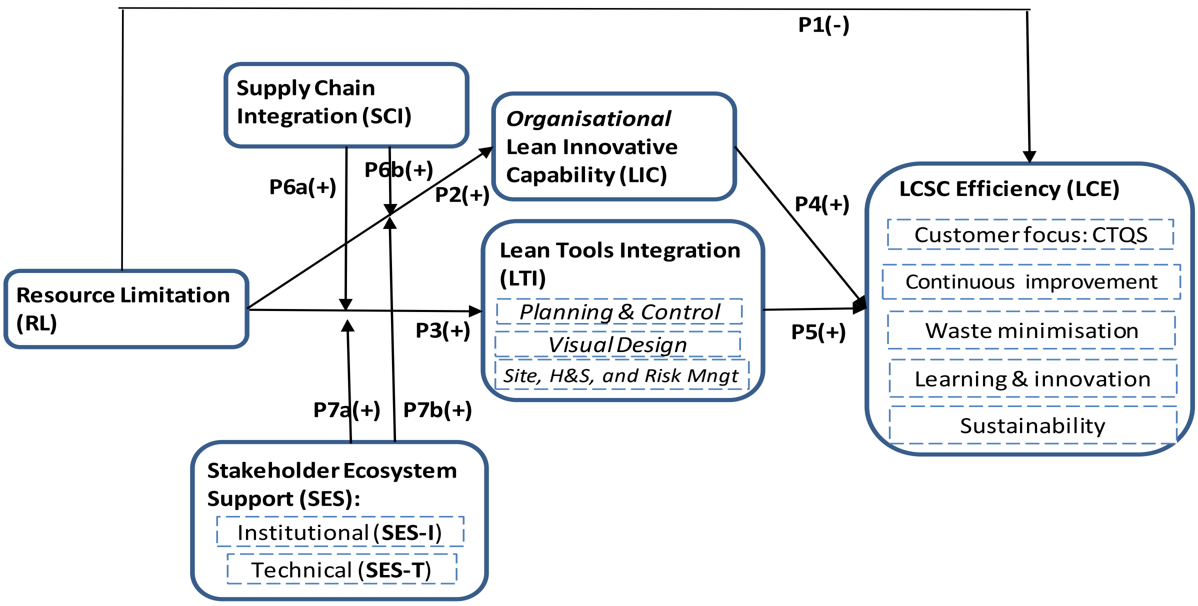
Prior studies have presented various model relationships (see Table 1). For example, a hypothetical LCSC model that employed the study between the applicability of lean principles, construction supply chain collaboration and project performance, centred on key elements (customer focus, continuous improvement, learning and innovation, waste minimization) for lean construction success was established by Meng (2019). However, the impact of the relationship on each construct was not tested and lacked validation. Demirkesen and Bayhan (2020) explored lean construction success factors and clustered them into; financial, managerial, technical, workforce, culture, government and communication. Their results revealed that lean training, availability of lean tools and techniques and market share were lean implementation's most important success factors. Although their findings demonstrated potential to improve efficiency, their study offered little understanding on how resource limitation among project actors could be addressed by vibrant supply chain integration, stakeholder ecosystem support and lean innovative capability of AEC organisations. Table 1 summarizes other models and their contributions adopted by various researchers in construction. LCSC models related to other industries (such as manufacturing) were excluded in this study.

[3] Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Table 1. Summary of previous LCSC models

Author(s)	Model Main Constructs	Methods/Theory	Contribution
Meng (2019)	Applicability of lean principles, lean CSC collaboration, and project performance.	Interviews and descriptive statistics	Lean principles are found to apply to various types of construction projects. Lean management has an impact on project performance.
Demirkesen & Bayhan (2020)	Success factors are clustered as financial, managerial, technical, workforce, culture, government, and communication.	Analytical Network Process (ANP) model based on Importance Weights	These constructs are considered key lean implementation success factors.
Le & Nguyen (2023)	Virtual design construction (design integration), project planning and control, onsite construction and safety management, and sustainable CSC performance.	Integrated Delphi – Fuzzy AHP Process	Proposed a strategic and operational framework for Lean Construction (LC) practices' contributions to sustainable CSCM trends in the forthcoming years.
Asadian & Leicht (2022)	Construction teams, LPS procedure, social interactions, team dynamics, and planning performance.	"Interaction Process Analysis" (IPA)	Proposed an untested hypothesized model.
Zhang & Wu (2011)	Implementation ability, process management, lean degree of employee, lean improvement culture, and adaption ability.	Analytical Network Process (ANP)	Offered an appraisal model to improve Lean implementation ability in China's construction industry.
This study	Resource limitation (RL), Lean tools integration (LTI), Supply chain integration (SCI), Stakeholder ecosystem support (SES), Lean innovative capability (LIC), LCSC efficiency (LCE)	Theory of constraints, lean and supply chain integration theories; structural equation/regression modelling	Proposes a strategic and pragmatic (operational) model for an integrated LCSC in construction. Its successful deployment is instrumental in achieving LCSC efficiency (LCE).

The synthesis summarized in Table 1 suggests that models that integrate lean approaches and construction supply chain constructs are lacking. In addition, a considerable chunk of studies on the phenomenon was conducted adopting mainly; integrated Delphi – Fuzzy AHP process and related Multi-criteria Decision-making (MCDM) methodologies. However, despite substantial attempts to utilize MCDM models, these studies were dominated by conceptual and relatively few empirical studies. They lacked other logics that may further expand and enrich our understanding on theoretical and empirical implications. Moreover, models that employed structural equation modelling and multivariate regression analysis techniques were lacking in these studies. Therefore, this study proposes an initial LCSC remodeling that is more comprehensive and pragmatic for value addition, which will be tested and validated by employing these techniques. To achieve an integrated LCSC model and to limit the envisaged empirical investigations and discussions, we select six (6) constructs (see Figure 1) as key predictors influencing LCSC efficiency. Referring to the research question and drawing on the proposed theoretical framework, the selected theoretical constructs include: (1) resource limitation, (2) lean tools integration, (3) supply chain integration, (4) lean innovative capability, (5) stakeholder ecosystem support and (6) LCSC efficiency. Although there could be diverse ways of remodeling LCSC, the basis for selecting these constructs is anchored on two basics: (1) the model aims at addressing the identified supply chain problems in Tanzania, and (2) the theoretical underpinning is backed by conceptual model building literature which underscores that, models (conceptual, numerical, statistical) are simplifications (reductions) of complicated real-life scenarios (Bernard & Ryan, 2010; Imenda, 2014). The combined effects of these two basics support pragmatists' view in which the behavior of one construct impacts another construct (Imenda, 2014; Greene et al., 1989), thus concretizing LCSC efficiency. For example, it can be noted that; the identified problems and effects (i.e. inappropriate delivery practices, delays, rework, waste etc.) can be addressed by integrating sufficient lean tools pegged on the lean theory. Resource limitations (such as finance, knowledge, technologies etc.) could be swiftly leveraged by the aura of lean innovative capabilities (Johnson et al., 2023; Meng et al., 2019). Further, inefficient procurement systems can be improved through effective integration of supply chain strategy that involves key resourceful supply chain actors/partners grounded on supply chain integration theory. Moreover, inadequate capital and a lack of industrial policies, building codes, and incentives can be intervened through stakeholder support systems (institutional/technical) based on stakeholder resource-based view (RBV) theory. The model will benefit contractors, consultants, and developers. The subsections that follow expound these constructs along with propositions.



Note: H&S – Health & Safety; Mngt. – Management; CTQS – Cost, Time, Quality, Safety; P – Proposition.

Figure 1. Proposed conceptual model

DISCUSSION

PROPOSITION ONE

Johnson et al. (2023) indicate that innovation requires human capital and other assets, such as equipment and supplies as resources (Johnson et al., 2023). While some firms do better than others, it stands out that with no strategic resources, there will be no innovation (Johnson et al., 2023; Li et al., 2022). Empirical studies have employed different theoretical frameworks and have developed various conceptual models to probe the effect of resource limitation on LCSC efficiency (Johnson et al., 2023; Koskela et al., 2020). This study contends that the problems related to defective design, poor quality, inferior working conditions and low safety arrangements, coupled with resource constraints, have a detrimental impact on LCSC efficiency. As stated earlier, empirical studies on slack and its effects on innovation suggest that performance increases as resources increase up to a point where incremental costs exceed benefits, resulting in an inverted-U shape metric (Johnson et al., 2023). In contrast, an opposite trend occurs as resources get diminished. Prior research substantiates that innovation decreases relative to cases where resources are plentiful, in which firms with low levels of slack had the lowest innovation levels (Johnson et al., 2023; Troilo et al., 2014). This will in turn negatively impact LCSC efficiency. Thus, it can be postulated:

P1: Resource limitation has a negative impact on LCSC efficiency.

PROPOSITION TWO AND THREE

As discussed, the lean concept is centred on creating value for customers with fewer resources (Drevland & Lohne, 2023; Mossman, 2018). It optimizes resource efficiency and time/schedule constraints and ensures the budget is not exceeded, thus satisfying the customer (client/employer) (Mossman, 2018). According to Meng (2019), “wasteful processes and activities consume resources but do not add value to the final deliverables” (p. 3787). Therefore, lean, innovative efforts to remove all non-value-adding processes and activities are vital for lean construction (Koskela et al., 2020; McSharry et al., 2023; Meng, 2019). Prior empirical studies on slack (plentiful resources) and its effects on innovation suggest that performance increases as resources increase to a point where incremental costs exceed benefits, resulting in an inverted U shape (Johnson et al., 2023). However, circumstances in which resources are constrained (similar to having lower slack/munificent resources “relative” to other industry players) but where organizations continue to innovate successfully reflect conditions of lean innovation (Johnson et al., 2023; Troilo et al., 2014). This lean innovative capability enhances organisations achieve innovation performance with limited resources. At the same time, to achieve this aim in the AEC project context, the integration of lean tools comes into effect. For example, planning and controlling tools such as LPS are confirmed to have far superior project results (Liu et al., 2022; Warid & Hamani, 2022). Their main strength is their ability to handle uncertainties by increasing planning reliability and predictability, thus decreasing workflow variability (Liu et al., 2022; Warid & Hamani, 2022). Hence, it is propositioned:

P2: The negative impact of resource limitations/constraints is positive when lean innovation capability is high.

P3: The negative effects of resource limitations/constraints turn positive when lean tools integration is high and robust.

PROPOSITION FOUR

As stated earlier lean innovation capability (LIC) of an organization is its ability to achieve sustainable innovation performance that meets core customer needs while constantly and effectively leveraging resource limitations (Johnson et al., 2023). Drawing insights from this perspective, we argue that AEC firms (especially start-ups), usually characterized by a financial, human, and material resource shortage, fail to achieve LCSC efficiency. These effects constrain construction production, exchange, and consumption (Johnson et al., 2023; Koskela et al., 2020; Troilo et al., 2014). LICs (such as product-market fit, experimentation culture, mission-oriented leadership, and network learning capability) can significantly improve LCSC efficiency (Hong et al., 2019; Johnson et al., 2023). For instance, visionary leadership provides clear and decisive directions for an organisation, symbolizing strategy and culture on what to do and why (Johnson et al., 2023; Lello et al., 2023). Prior research showed that innovative companies under resource constraints had managers who focused on translating innovation strategies into strategic goals, objectives and performance (Hong et al., 2019; Johnson et al., 2023; Meng, 2019). We also argue that we can use the LIC construct to set a baseline effect to test for positive mediation in leveraging the negative effects of resource limitation, thus improving LCSC efficiency. Therefore, we opine:

P4: LIC has a significant and positive impact on LCSC efficiency.

P4a: LIC positively mediates the relationship between resource limitation and LCSC efficiency, such that the negative impact of resource limitation turns positive when LIC is high.

PROPOSITION FIVE

To achieve LCSC efficiency (i.e., value creation for end customers, waste minimization, etc.), lean tools integration (LTI) plays a vital role. It includes key tools that a main contractor can use to improve predictability, eliminate variability in production (Liu et al., 2022; Warid & Hamani, 2022) through standardization, and reduce lead time (Broft, 2019). As previously described, these key lean tools include the last planner system, building information modelling, target value design, choosing by advantages, just in time, to mention a few. Studies indicate that effectively using these tools has significantly improved lean construction performance (Broft, 2020; Koskela et al., 2020; Le & Nguyen, 2023). Scholars (e.g. Le & Nguyen, 2023; Liu et al., 2022) grouped these lean tools into four categories: design and engineering, planning and control, construction and site management, and health and safety management. This study also suggests that the negative impact of resource limitation on LCSC efficiency is leveraged by LTI mediation. Studies that have examined this relationship are limited. Remodelling resource limitation and LCSC efficiency without factoring LTI cannot yield the envisaged LCSC efficiency. Thus, it can be opined:

P5: LTI has a significant and positive impact on LCSC efficiency.

P5a: LTI positively mediates the relationship between resource limitation and LCSC efficiency, such that the negative impact of resource limitation turns positive when LTI is high.

PROPOSITION SIX

The lean approach challenges scholars to fundamentally rethink value from the customer's needs (Broft, 2020; Koskela et al., 2020). According to Broft (2020), this includes the identification of the 'entire' value stream. The value stream is "the set of all the specific actions (including key project stakeholders) required to bring a specific product or service through the critical management tasks of any business" (Broft, 2020, p. 280). In supply chain integration (SCI), all key supply chain actors need to be able to make a full contribution to ensure that the client's needs are fulfilled and that value creation is maximised (Broft, 2019; Li et al., 2022; Malaeb & Hamzeh, 2018). Drawing on the flow model of production perspective, where production is conceived as a flow of materials and semi-products leading to an integrated final product (Koskela et al., 2020), the analysis of these construct relationships argues that both internal and external SCI can positively moderate the relationship between resource limitation and lean tools integration as well as between resource limitation and lean innovative capability. According to Koskela et al. (2020), any form of waste, i.e., non-value-adding activities existing in the production system of the organisations within the supply chain, will need to be reduced or removed. Vibrant organisation and governance of key supply chain actors (suppliers,

specialized subcontractors, etc.), processes and activities can lead to high productivity and fast delivery (Ballard & Elfving, 2020; Broft, 2019; Le & Nguyen, 2023). To achieve this effect, robust lean tools integration is inevitable. However, to effectively plan, design and control (by employing lean tools) the works (material handling, site logistics and productivity, etc.), strategic engagement with key supply chain actors should be considered (Dakhli & Lafhaj, 2022; Le & Nguyen, 2023). This can positively leverage any negative impact of resource limitation on both lean tools integration and lean innovative capability. Prior research demonstrated that a 7% to 8% improvement is attributed to construction site logistics and supply chain management (Dakhli & Lafhaj, 2022). Thus, SCI has the potential to act as a critical vector and catalyst between resource limitation and lean tools integration as well as between resource limitation and LIC, where innovative lean tools coupled with lean innovative capability must be orchestrated. Therefore, it can be suggested:
P6: SCI moderates the relationship between resource limitation and lean tools integration (**6a**) and between resource limitation and lean innovative capability (**6b**).

PROPOSITION SEVEN

Stakeholder research in AEC focuses mainly on key inbound (direct/core) supply chain actors such as customers, suppliers, and subcontractors (Koskela et al., 2020; Lello et al., 2023; Li et al., 2022). Outbound (indirect/peripheral) supply chain actors, such as government institutions, have been overlooked in LCSC contexts. Given the resource constraints that characterize the AEC industry, construction organisations are always under pressure to deliver projects successfully. This is attainable when these organisations employ innovative lean tools (Koskela et al., 2020; Le & Nguyen, 2023) and lean innovative capability (Johnson et al., 2023). However, strategic integration with peripheral partners (such as institutional stakeholders and IT vendors) can greatly foster corporate flexibility and quick responsiveness (Johnson et al., 2023; Malaeb & Hamzeh, 2018). The delivery of AEC projects involves knowledge- and service-intensive undertakings usually regulated by third-party stakeholders (government/regulatory organs) (Lello et al., 2023; Yip et al., 2019). These stakeholders provide strategic policy frameworks, such as building codes, environmental certifications, and safety guidelines (Lello et al., 2023; Yip et al., 2019), influencing lean tools integration and lean innovative capability. To attain this, AEC designers must seek ways to incorporate all stakeholder interests and then transform the interests into clear design specifications for the new product/service development process (Lello et al., 2023; Yip et al., 2019).

Data science innovations are widely considered as unequivocal vectors for supporting not only SCI but also information sharing, knowledge/skills and innovation networks. For instance, IT vendors, which are also key stakeholders, play a pivotal role in providing the necessary supporting IT infrastructure (e.g. BIM, AI, blockchain, big data analytics, etc.) (Adekunle et al., 2023; Dakhli & Lafhaj, 2022; Liu et al., 2022). In the current digital era (industry 4.0 & 5.0), this technical support employing big data and Internet of Things provides innovative methods that aid organizations in developing high-performing teams and a culture that is performance-focused (Adekunle et al., 2023; AlBalkhy et al., 2023). Nascent studies are now shedding light on the application of technical supports to deal with the problem of lack of synchronization, which has constantly hindered creation of a stable flow in the production system, thus degrading performance and value creation (Lello et al., 2023; AlBalkhy et al., 2023). This will thus leverage the negative impacts of resource limitation on both lean tools integration and lean innovative capability. It can be postulated:
P7: Stakeholder ecosystem support (both institutional and technical) positively moderates the relationship between resource limitation and lean tools integration (**7a**) as well as between resource limitation and lean innovative capability (**7b**).

No prior research has proposed such an integrated model (see Figure 1). In this context, its realization will unfold a novel contribution to theory and practical implications. Moreover, to measure/test and validate the theoretical constructs, the proposed LCSC remodeling will use indicators well-established in previous studies in the literature. For instance, scholars will identify these variable indicators mainly based on the Integrated Delphi – Fuzzy AHP Process (e.g. Le & Nguyen, 2023; Demirkesen & Bayhan, 2020). One of the advantages of this approach is the ease of comparison among alternatives and easy adjustment (Demirkesen & Bayhan, 2020).

CONCLUSIONS

Achieving LCSC efficiency of the AEC projects has been hindered by the lack of an integrated and pragmatic LCSC model that can aid in the alleviation of cost overruns, time overruns, supply chain quality concerns, environmental and safety challenges. Based on a critical literature review approach, this study was conceptualized to solve the mentioned problems to eliminate resource waste (non-value adding activities) through LCSC. Drawing on insights from the lean theory and SCI view, six (6) theoretical constructs were identified as key variables in developing a novel LCSC model for deployment by the AEC actors (e.g. contractors, consultants, developers etc.). Future studies will examine the seven (7) propositions closely to gauge if hypotheses that can be measured can then be developed and tested. In this study, a proposition tries to suggest a link between two or more concepts that may not be tested scientifically while a hypothesis can be tested to estimate the impact of these relationships on LCSC efficiency. Undertaking this endeavor is instrumental in identifying, understanding and removing constraints in operations thus aiding work progress. Therefore, this study presents not only a preliminary step of a doctoral study but also lays a potential foundation on how the theory informs future empirical investigation in eradicating LCSC problems using sample data from Tanzania, thus contributing to and advancing the LCSC literature. The research will further elicit responses from industry participants to answer the research questions and draw up recommendations for the main study. It will further aid theoretical, empirical, practical and policy implications in achieving LCSC efficiency in the construction industry.

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REFERENCES

Adekunle, P., Aigbavboa, C., Oke, A., Akinradewo, O., & Otasowie, O. (2023). Application of Big Data and Internet of Things in the Built Environment: A Bibliometric Review. Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31), 50–58. https://doi.org/10.24928/2023/0138

AlBalkhy, W., Rankohi, S., Lafhaj, Z., Iordanova, I., Velasquez, J. M. R., Bourgault, M., & Pellerin, R. (2023). Lean and IoT Integration to Improve Flow in Construction Prefabrication: a Proposed Framework. Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31), 836–845.

Asadian, E., & Leicht, R. M. (2022). Social Interactions and Team Dynamics in a Last Planner Meeting: An Observational Method. 30th Annual Conference of the International Group for Lean Construction, IGLC 2022, 480–491. https://doi.org/10.24928/2022/0153

Bajjou, M. S., & Chafi, A. (2020). Identifying and Managing Critical Waste Factors for Lean Construction Projects. *Engineering Management Journal*, *32*(1), 2–13.

Ballard, G., & Elfving, J. (2020). Supplier Development: The Gateway to Supply Chain Management in the Construction Industry. In Lean Construction Journal (Vol. 2020). www.leanconstructionjournal.org

Bernard, H. R., & Ryan, G. W. (2010). Analyzing Qualitative Data: Systematic Approaches (2nd Edn.). SAGE Publications Inc.

Broft, R. D. (2019). Lean supply chain management in construction: Implementation at the "lower tiers" of the construction supply chain. In Successful Construction Supply Chain Management: Concepts and Case Studies: Second Edition (pp. 271–287). wiley.

Chauhan, K., Peltokorpi, A., Abou-Ibrahim, H., & Seppänen, O. (2022). Mechanical, Electrical and Plumbing Coordination Practices: Case Finnish Construction Market. 30th Annual Conference of the International Group for Lean Construction, IGLC 2022, 635–644. https://doi.org/10.24928/2022/0169

Cigolini, R., Gosling, J., Iyer, A., & Senicheva, O. (2022). Supply chain management in construction and engineer-to-order industries. In Production Planning and Control (Vol. 33, Issues 9–10, pp. 803–810). Taylor and Francis Ltd. https://doi.org/10.1080/09537287.2020.1837981

Dakhli, Z., & Lafhaj, Z. (2022). The Interplay between Construction Supply Chain and BIM through Kitting. In Lean Construction 4.0 (pp. 82–97). Routledge. https://doi.org/10.1201/9781003150930-8

Demirkesen, S., & Bayhan, H. G. (2020). A Lean Implementation Success Model for the Construction Industry. *Engineering Management Journal*, *32*(3), 219–239.

Drevland, F., & Lohne, J. (2023). Untangling the Concepts of Value and Values. Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31), 572–583. https://doi.org/10.24928/2023/0178

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a Conceptual Framework for Mixed-Method Evaluation Designs. Educational Evaluation and Policy Analysis, 11(3), 255–274. https://doi.org/10.3102/01623737011003255

Imenda, S. (2014). Is There a Conceptual Difference between Theoretical and Conceptual Frameworks? *Journal of Social Sciences*, *38*(2), 185–195. https://doi.org/10.1080/09718923.2014.11893249

Johnson, W. H. A., Bicen, P., & Zhu, Z. (2023). Being lean: Conceptualizing and operationalizing the Lean Innovation Capability (LIC) of innovative companies. *Technovation*, *126*. https://doi.org/10.1016/j.technovation.2023.102794

Kikwasi, G. J., & Escalante, C. (2020). The Construction Sector in Tanzania. In Mining for Change (pp. 256–281). Oxford University Press Oxford. https://doi.org/10.1093/oso/9780198851172.003.0012

Kikwasi, G. J., & Sospeter, N. G. (2023). Challenges Facing Supply Chain Management on Time Delivery of Construction Projects in Tanzania. In Lecture Notes in Civil Engineering (Vol. 245, pp. 257–267). Springer Science and Business Media Deutschland GmbH.

Koskela, L., Vrijhoef, R., & Dana Broft, R. (2020). Construction Supply Chain Management through a Lean Lens. In Successful Construction Supply Chain Management (pp. 109–125). Wiley. https://doi.org/10.1002/9781119450535.ch6

Le, P.-L., & Nguyen, D.-T. (2023). Exploring Lean Practices' Importance in Sustainable Supply Chain Management Trends: An Empirical Study in Canadian Construction Industry. *Engineering Management Journal*, 1–26. https://doi.org/10.1080/10429247.2023.2187608

Lello, D., Huang, Y., Emuze, F., & Alananga, S. (2023). Professional knowledge infusion and service performance within outbound consultant-supplier interfaces in Tanzania's construction industry: can networking and stakeholder support play cards? *International Journal of Construction Management*, 1–12. https://doi.org/10.1080/15623599.2023.2286049

Li, S., Huo, B., & Han, Z. (2022). A literature review towards theories and conceptual models of empirical studies on supply chain integration and performance. *International Journal of Production Economics*, 250(April), 108625. https://doi.org/10.1016/j.ijpe.2022.108625

Liu, C., González, V. A., Pavez, I., & Davies, R. C. (2022). Exploring the Socio-Technical Nature of Lean-Based Production Planning and Control Using Immersive Virtual Reality. In V. A. González, F. Hamzeh, & L. F. Alarcón (Eds.), Lean Construction 4.0: Driving a Digital Revolution of Production Management in the AEC Industry (pp. 172–191). Routledge. https://doi.org/10.1201/9781003150930-14

Malaeb, Z., & Hamzeh, F. (2018). A Lean Perspective of Stakeholder Integration in Public Private Partnerships. IGLC 2018 - Proceedings of the 26th Annual Conference of the International Group for Lean Construction: Evolving Lean Construction Towards Mature Production Management Across Cultures and Frontiers, 1, 3–12.

Manda, E., Mwanaumo, E., Thwala, W. D., Kasongo, R., & Chisumbe, S. (2023). Sustainable Education and Development – Sustainable Industrialization and Innovation. In C. Aigbavboa, J. N. Mojekwu, W. D. Thwala, L. Atepor, E. Adinyira, G. Nani, & E. Bamfo-Agyei (Eds.), Sustainable Education and Development – Sustainable Industrialization and Innovation (Vol. 3). Springer International Publishing.

McSharry, T., McHugh, K., & Koskela, L. (2023). Analysis of Lean Construction Cases in Ireland. Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31), 966–977. https://doi.org/10.24928/2023/0216

Meng, X. (2019). Lean management in the context of construction supply chains. *International Journal of Production Research*, 57(11), 3784–3798.

Mossman, A. (2018). What Is Lean Construction: Another Look - 2018. IGLC 2018 - Proceedings of the 26th Annual Conference of the International Group for Lean Construction: Evolving Lean Construction Towards Mature Production Management Across Cultures and Frontiers, 2, 1240–1250. https://doi.org/10.24928/2018/0309

Perdana, Y. R., Ciptono, W. S., & Setiawan, K. (2019). Broad span of supply chain integration: theory development. In International Journal of Retail and Distribution Management (Vol. 47, Issue 2, pp. 186–201). Emerald Group Holdings Ltd. https://doi.org/10.1108/IJRDM-03-2018-0046

Sarhan, S., Elnokaly, A., Pasquire, C., & Pretlove, S. (2018). Lean construction and sustainability through IGLC community: A critical systematic review of 25 years of experience. IGLC 2018 - Proceedings of the 26th Annual Conference of the International Group for Lean Construction: Evolving Lean Construction Towards Mature Production Management Across Cultures and Frontiers, 2, 933–942.

Trolio, G., De Luca, L.M., Atuahene-Gima, K. (2014). A more innovation with less? A strategic contingency view of slack resources, information search, and radical innovation. *J. Prod. Innovat. Manag., 31* (2), 259–277.

Warid, O., & Hamani, K. (2022). Lean Construction in UAE: Implementation of Last Planner System. Lean Construction Journal, 1–20. www.leanconstructionjournal.org

Yip, M. H., Phaal, R., & Probert, D. R. (2019). Integrating Multiple Stakeholder Interests into Conceptual Design. *Engineering Management Journal, 31*(3), 142–157.

Zhang, H., & Wu, C. (2011). The Analysis of Lean Implementation Ability and Its Appraisal Model. 2011 IEEE 18th International Conference on Industrial Engineering and Engineering Management: Proceedings: September 3-5 2011, Changchun, China.

Zimina, D., & Pasquire, C. L. (2011). Applying lean thinking in commercial management. *Journal of Financial Management of Property and Construction, 16(*1), 64–72. https://doi.org/10.1108/13664381111116098