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BUILDING A LEAN HOUSE WITH THE THEORY OF CONSTRAINTS FOR CONSTRUCTION OPERATIONS IN ZIMBABWE: A CONCEPTUAL FRAMEWORK

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ABSTRACT

The poor performance of construction projects in Zimbabwe, evidenced by cost overruns, extensive delays, reworks, defects, and accidents, has resulted in the need for cost-effective strategies such as the theory of constraints and lean construction (LC). This is because Lean drives out waste, and the theory of constraints (TOC) identifies constraints on which to act to improve performance. By focusing Lean initiatives on construction projects, TOC will lead to better improvements in performance. Although similar studies have been undertaken in other countries, they need to be more contextually relevant due to the myriad of economic challenges synonymous with the Zimbabwean construction industry. A critical review of relevant literature was conducted to observe how TOC allows for identifying constraints hindering progress on construction projects while LC tools would provide solutions. In effect, LC and TOC could reverse poor outcomes of construction operations in Zimbabwe. This conceptual paper thus proposes a framework that identifies constraints using TOC, followed by an evaluation of Lean tools suitable to deal with the identified constraints. The foundation of the lean house will engender effective problem-solving to remove bottlenecks in the design and construction processes.

KEYWORDS

Construction operations, Lean, theory of constraints, performance, Zimbabwe

INTRODUCTION

Construction projects involve various actors whose activities greatly influence project success, such as the client or project owner, the consultant (architects, engineers, and quantity surveyors), and the contractors (Jin et al., 2017). Even though these parties have one goal: to make a profit, the multi-party working situation involved in construction projects results in conflicts and disputes, which bring direct and indirect cost consequences to clients and contractors (Yates and Hardcastle 2002). According to Goldratt (1991), every company's goal is to make money at present and in the future. The term constraint is defined as any element hindering the company's achievement of that goal. Theory of Constraints (TOC) is an approach that identifies the constraint and offers a solution for its mitigation (Pacheco et al., 2019). The TOC recognizes that constraints on any system restrict maximum performance concerning the goal (Siha, 1999). In the construction industry, that goal is to profit through increased productivity and minimized waste.

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Waste minimization can also be achieved through lean construction (LC). LC involves converting waste into value by reducing waste, improving communication, and promoting teamwork integration through common tools and techniques (Emuze et al., 2014; Srinivas, 2020). Furthermore, LC creates a culture where the occurrence of problems is minimal due to benefits such as a reduction of waste, a decrease in inventory, advanced quality, better system flexibility, reduced variability, and amplified problem visibility (Abdullah et al., 2009). In addition, it ensures conventional flow and an improved capability to deal with uncertainty and difficulty in construction project delivery (Ruin et al., 2016). Maske and Valunjkar (2020) postulated that the LC method had been extensively articulated in developed countries; however, it has yet to attain limited and contextual applications. Lean production is a technique that Toyota Motor Company first implemented in the 1950s (Aziz and Hafez, 2013). Lean Thinking was first introduced in construction by Koskela to tackle certain features of building projects (Salvatierra-Garrido et al., 2010). Koskela et al. (2002: 212) define LC as "a way to design production systems to minimize waste of materials, time and effort to generate the maximum possible value". Koskela (1992) highlights that construction could significantly improve by identifying and eliminating non-value-adding activities.

The profitability of most construction projects depends on construction productivity; if this is not fully addressed, projects will incur cost and time overruns (Besklubova and Zhang, 2019). According to Aziz and Hafez (2013), construction productivity has declined worldwide over the past 40 years, hence the need to implement approaches such as TOC and LC to improve performance. In Zimbabwe, cost, time and quality concerns remain prevalent in infrastructural construction projects (Moyo et al., 2019; Bhebhe, 2022). To add to this, Chazireni and Chagonda (2018) highlight health and safety inadequacies that also affect the performance of construction projects. Hence, cost, time, quality, and safety constraints hamper the success of construction operations in Zimbabwe. By combining LC and TOC, performance improvement can be achieved as waste will be eliminated from construction operations.

Although studies have been conducted on LC and TOC by Ju et al. (2000) in Singapore, Cameiro et al. (2009) and Santos et al. (2012) in Brazil, the implications of those results do not necessarily apply to Zimbabwe. This is because the construction industry in Zimbabwe is resource-restrained due to the foreign currency shortages, prolonged power outages, and ever-increasing inflation estimated at more than 400% experienced over the past five years (Kuwaza, 2019). Therefore, it is essential to identify cost-effective performance improvement strategies applicable to the unique situation currently experienced in Zimbabwe. Hence this paper is the first step of a doctoral study that aims to develop guidelines for using the theory of constraints (TOC) and lean to improve construction operations in Zimbabwe.

The Statement of the Problem

Challenges of time and cost overruns, quality issues, health and safety inadequacies, productivity, performance, and sustainability have been dominant in the construction industry in Zimbabwe (Chazireni and Chagonda, 2018; Mhlanga, 2019; Moyo and Chigara, 2021). Oke et al. (2019) also explained that waste, such as materials, resources, time, movement, production, and creativity, affect the construction industry's performance. Therefore, waste-laden construction operations in the Zimbabwean construction industry promote performance concerns related to cost, time, quality, and safety. Implementing lean tools, coupled with the fact that contractors do not know how to identify, understand, and remove constraints in construction operations, is yet to be operationalized as a resolution in the study area.

Therefore, this study seeks to provide a framework for TOC and LC to improve construction operations in Zimbabwe. The overall benefit is the achievement of key targets within the sustainable development goal of ensuring sustainable production and consumption patterns from the construction industry perspective (United Nations Department of Global Communications, 2020).

Primary research question and secondary research questions

The primary research question elicits responses to what can be done using the theory of constraints (TOC) and Lean to improve construction operations in Zimbabwe. The secondary research questions require responses on the following: what needs to change in construction operations, what can be done for construction operations to change, what can project actors do to cause the change in construction operations, what lean tools will improve construction operations, and what can be done through combining lean and TOC to improve construction operations in Zimbabwe based on literature.

These questions will be answered by first interrogating the causes of cost, time, quality, and safety challenges, thereby indicating what needs to change in construction operations in Zimbabwe. The mitigating strategies for these challenges are identified, highlighting how construction operations can change. Next, implementing the principles of the Toyota Production System (TPS) and Fukuda Production System (FPS) will be examined to show how they can cause the change required in construction operations. Also, lean tools that can improve construction operations regarding cost, time, quality, and safety performance will be assessed. Lastly, recommendations on what construction operation improvements can be achieved through combining the TOC and Lean.

PERFORMANCE OF CONSTRUCTION PROJECTS

The performance of construction projects has been topical over the past two decades, as alluded to by various authors hereafter.

COST PERFORMANCE OF CONSTRUCTION PROJECTS

Moyo et al. (2019) highlight the prevalence of cost overruns in construction projects and suggest the need for sufficient awareness and regulation on decent work conditions for construction workers as it has a bearing on their productivity. Nyoni (2019) indicates how rare it is in Zimbabwe for construction projects to be completed within the estimated budget, thus the importance of finding solutions to these cost performance challenges. According to Moyo and Chigara (2022), the performance of infrastructural projects has been challenging, thus leading to the interrogation of the causes of cost overruns in Zimbabwe. It is essential to identify the causes of cost overruns to cause the change required in the performance of construction projects in Zimbabwe.

TIME PERFORMANCE OF CONSTRUCTION PROJECTS

According to Nyoni and Bonga (2017a), the issue of delays is one of the severest performance challenges in construction projects, and their effect has a bearing on the overall economy of such developing nations. Nyoni (2018) also expresses concern over prevalent delays in most construction projects in Zimbabwe; he explains how these delays culminate in cost overruns and quality defects. Ngendakumana and Kakono (2020) studied the causes of construction project delays in Zimbabwe's public service and identified lack of adequate funds, project variations and inadequacy of resources as the major causes. Nyoni and Bonga (2017b), in their study of critical success factors in the construction sector, highlight the challenge of incomplete projects and postulate critical success factors to significantly improve project effectiveness and efficiency hence providing solutions to time performance and cost performance challenges.

QUALITY PERFORMANCE OF PROJECTS

In Zimbabwe, there has been great concern over poor workmanship on certain high-impact infrastructural projects countrywide (Bhebhe, 2022). This is evidenced by the recently opened registry building in Harare, which is already developing cracks, water leakages, and non-functioning elevators (Chibamu, 2022). This brings out the need for these performance improvement strategies, hence the importance of this study.

Safety Performance of Construction Projects

Chigara and Moyo (2014), postulate that there is a high injury frequency rate in the construction sector of Zimbabwe which is estimated at around 2.34%, therefore higher than the ILO-prescribed rate of less than 1%. Further, Chigara and Smallwood (2017) state that the Zimbabwean construction industry is still experiencing injuries at an increasing rate. Charizeni and Chigonda (2018) concur that safety challenges are prevalent on construction sites, hence the importance of continuous performance improvement.

This shows that cost, time, quality, and safety constraints hamper the success of construction operations in Zimbabwe. Additionally, diverse challenges affecting the construction industry's performance in Zimbabwe led Moyo and Chigara (2021a) to interrogate the barriers to implementing LC. These barriers included management-related, design management-related, technical issues, change management-related, quality management-related, and human capital management-related. These findings were supported by other researchers in developing countries (Khaba & Bhar, 2017; Sarhan, et al., 2018; Albalkhy & Sweis, 2020), as they also identified similar barriers. By combining LC and TOC, performance improvement will be achieved as waste will be eliminated in the parts of the system that are the most significant constraints.

THEORETICAL FOUNDATION

The study's theoretical foundation consists of the theory of constraints and lean theory, which are supported henceforth.

Theory of Constraints (TOC)

The TOC is a theory developed by Dr. Eliyahu Goldratt in 1984 (Goldratt and Cox, 2004). This theory suggests that every organization's goal is to make a profit. However, organizations' constraints hinder the achievement of this goal to make a profit. TOC identifies critical constraints and suggests improvement of activities that would elevate the constraints and inherently prioritize them (Upreti et al., 2020). Hence, TOC is a continuous improvement process because no matter how successful an organization is in achieving its goals, constraints will always exist; hence, TOC focuses on identifying and managing these constraints within organizations (Pegels and Watrous, 2005). Goldratt (1991) identified five steps of the focus process of managing these constraints within organizations, including identifying the constraints, deciding how to exploit the needs of the constraint, subordinating and synchronizing the constraints, elevating the constraints, and, lastly, repeating the process. These steps form the foundation of this study. Therefore, TOC is expected to play a significant part in improving performance.

Lean Approach for Construction

Lean principles aim at eliminating or reducing non-value-adding activities (e.g. waste, variation, waiting, low standard) and promoting value-adding activities (e.g. ensuring quality and safety, sustainability, environmentally friendly, customer satisfaction) (Ahmed et al., 2021). Although each organization must develop its way of doing business, The Toyota Production System (TPS) has achieved success for Toyota in terms of waste minimization and value addition. This success makes it a solid foundation for implementing lean principles. The TPS's 14 principles are critical for achieving and responding to constraints as they are supported by pillars of continuous improvement and respect for people (Liker, 2004). In Japan, the TPS was adapted for construction projects by the FPS to improve the efficiency of construction work and lower construction costs (Nakagawa and Shimizi 2004). The FPS flow was suggested as follows:

1. Setting the goal
2. Establishment of indices to achieve the goal (this involves the establishment of Just In Time, and Standard Operating Procedure Documents (SOPD)
3. Setting of target figures for the indices (this includes continuous revisions to the SOPD and target figures)
4. Implementation to attain the goal (this involves checks and confirmations on whether the goal is being achieved.
5. Checking and confirming that target figures have been achieved (If the goal is not achieved, then the cause is examined, and if the goal is achieved, then the procedural steps are standardized
6. Continuous Improvement

The FPS is a more feasible foundation for implementing LC guidelines in the Zimbabwean construction industry. The FPS has the potential to respond to the constraints in the 'setting of the goals' stage and accommodates LC tools within its flow. Above all, it caters to continuous improvement, allowing for the constant generation of constraints and appropriate responses.

METHODOLOGY

The conceptual paper is based on the critical literature review of the theory of constraints and LC theory. The conceptual framework developed is the preliminary stage of a doctoral study expected to solve the challenges of performance experienced in construction operations in Zimbabwe. The study is based on the review of literature on TOC, LC tools, and performance challenges in the Zimbabwean construction industry. The keywords for the search included "Theory of constraints", "Lean construction with the theory of constraints", "lean tools", lean construction", lean construction tools", "lean house", and "Zimbabwean construction constraints". The search was dominated by, but not limited to, Emerald, Science Direct, relevant textbooks on TOC, and publications in the International Group of Lean Construction (IGLC) repository. Articles relating to developing countries were preferred as the study context aligned more with them. An attempt was made to consider the latest articles where it was possible. Content analysis was employed to extract relevant information for developing the conceptual framework, as shown in Figure 1.

CONCEPTUAL FRAMEWORK

Figure 1 shows the proposed framework for providing TOC and Lean guidelines for improving construction operations. The foundation of the lean house is built on ensuring standardization and stability in responding to constraints within construction operations. Achieving this culminates in guidelines that can be utilized for construction operations. The TOC is also foundational as a continuous process for identifying new constraints as and when they become significant. The identification of constraints using the TOC requires two main pillars. The first pillar is the Lean tools that can be implemented to resolve and continuously improve the constraints.

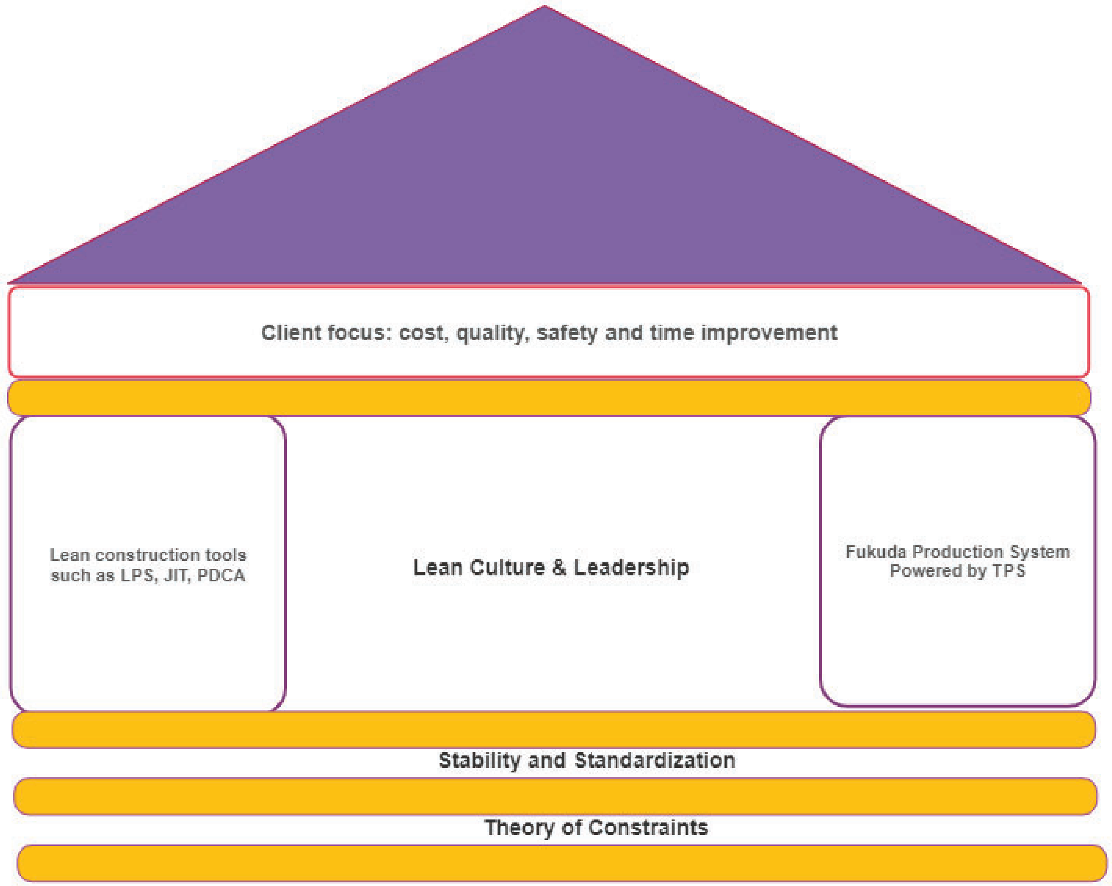

Figure 1: Conceptual Framework- Lean house with the theory of constraints

The lean tools are expected to be implemented in accordance with the TOC steps of identification, exploit, subordinate, elevate and repeat. These lean tools include the Last Planner System, Total Quality Management, Just-in-time and PDCA. The selection of lean tools should be based on context, usability in developing countries and the ability of the tools to contribute to the continuous improvement of construction operations. The other pillar encourages the adoption of the TPS principles as adopted within the construction industry as the FPS. The requirements of the two pillars can only be achieved through adopting lean leadership and organizational culture. All project actors must inculcate lean leadership and organizational culture for the guidelines to be successful. Using lean tools, the FPS principles must lead to cost, time, quality and safety improvements in construction operations. This is envisaged to be a continuous improvement process. The constituents of the proposed framework are briefly reviewed henceforth.

CONSTRUCTION OPERATIONS CONSTRAINTS

To improve construction operations in Zimbabwe, several changes are required in the aspects of cost, time, quality, and safety. Cost aspects require changes in respect of low productivity of the workforce, idle plant and machinery, material wastage on construction sites as well as plant and machinery inefficiency as these have caused poor performance of construction operations. Moreso, changes in time aspects are necessary, including low productivity of the workforce resulting in delays, ineffective coordination, and poor communication among stakeholders. There are also quality changes required to improve the quality performance of operations, and these are the occurrence of defects, reworks, use of poor quality materials, and poor workmanship. Finally, the safety aspects that require change are the number of accidents on construction sites, the frequency of absenteeism of workers from sites, high employee turnover, and low workforce morale.

The abovementioned changes are required to create simple and practical solutions to construction operations' cost, time, quality, and safety challenges. Therefore, effecting the changes suggested will result in increased productivity, less waste paying for idle plant and machinery, efficient use of materials and efficiency of plant and machinery hence improving cost performance of construction operations. Achieving the changes required for time aspects will result in enhanced productivity of the workforce, effective coordination of work, and effective communication amongst stakeholders, thus solving the challenge of delays. Moreso, changes in quality challenges will result in the minimization of reworks, reduced defects, improved quality of end products, and achievement of client satisfaction. Lastly, safety changes will lead to reduced accidents and incidents, reduced absenteeism, and employee turnover, thus increasing productivity and improvement in the morale of workers.

To build a secure and stable improvement environment for the changes required, the research proposes using the FPS, which was developed specifically for construction projects from the TPS. The FPS has principles that allow for performance improvement of construction operations by setting goals for the whole organization, individuals, and construction projects. The principles enable setting safety and quality standards on construction projects required for individuals, construction projects and the organization. Furthermore, these principles provide an improved environment for cost and time challenges. It allows for the identification and continuous reduction of waste, which is the main cause of cost and time overruns. Moreover, the principles allow for continuous improvement through its people-centred approach, realizing that performance can only be achieved if employees are trained, offered incentives for waste reduction, and involved at every stage.

LEAN CONSTRUCTION TOOLS

A plethora of Lean tools exists in the manufacturing and construction sectors. However, the nature of the manufacturing and construction industries varies with the relevant Lean tools (Moghadam and Al-Hussein, 2014). Therefore, selected lean tools relevant to the construction industry are reviewed in Table 1.

Also, the major findings and the constraints addressed in those studies are presented and analyzed for inclusion in the study’s conceptual framework. It is practically impossible to operationalize all the suggested LC tools in this study. From the findings in Table 1, the LC tools most effectively responding to cost, time, quality, and safety include the Last Planner System (LPS) and Total Quality Management (TQM). LPS has been the most common LC tool utilized by many researchers, while TQM had a significantly high impact on individual performance, as reported by Li et al. (2019). In addition, the FPS suggests using the Just-in-time (JIT) and Plan, Do, Check and Act cycle (PDCA) on construction sites (Nakagawa and Shimizu, 2004). Therefore, this study has incorporated the LPS, TQM, JIT and PDCA tools for contextualization and standardization within the Zimbabwean construction industry to resolve the constraints of cost, time, quality, and safety. The LPS shapes workflow and responds to project variability in construction (Ballard, 2000). TQM ensures quality management of every stage of construction operations and continually invests in improvement opportunities (Radnor, 2000). The JIT tool reduces waste by ensuring the delivery of materials when required, while the PDCA periodically emphasizes safety, schedule, and quality improvements (Nakagawa and Shimizi, 2004).

Table 1: Lean construction tools from previous studies

Lean construction tools	Findings	Source	Constraints targeted
Last planner system	The proposed Last planner system could significantly improve productivity in developing countries.	Ahiakwo et al (2012)	Cost and Time
Last planner system, Increased visualization, The Five S's Process, Fail Safe for Quality and safety, First, run studies.	Although respondents agreed on their importance, their implementation could be improved by a lack of awareness.	Enshassi and Abu Zaiter (2014)	Safety
Last planner system	Success was achieved on sites where total management commitment was made towards lean tool implementation.	Raghavan et al (2014)	Time
5S, Quality control and Last planner system	The last planner system enabled the monitoring of improvement actions	Berrior et al. (2015)	Cost, Time and Quality
Last planner system	Existing gaps in planning and scheduling vs last planner systems	Dave et al. (2015)	Time
Planning and controlling the production, Kanban, Autonomation, Flows, Production, Transparency, Cleanness, organization and safety.	Lean audit checklist for the various sites' implementation of a standardized manual on lean tools revealed a positive contribution to project performance goals.	Fernandes et al (2016)	Cost, Time, Quality and Safety
Last planner system	The lean tool successfully contributed to the successful completion of four case study projects concerning cost, time and safety.	Karanjawala and Baretto (2018)	Cost, Time, Safety
Last planner system	Work involvement by the last planner improved the performance of the project.	Sundararajan and Madhavi (2018)	Time
Last planner system, a Visualization tool, Six step plan (6S), Just-in-time (JIT), Total quality management (TQM)	TQM had the highest impact on individual performance, while the Last planner system had the least.	Li et al. (2019)	Cost, Time, Quality and Safety
Last planner system	Implementation of the tool led to a positive impact during the COVID- 19 pandemic	Veran-Leigh and Brioso (2019)	Cost, Time, Quality and Safety

Performance Improvement

The competition in the construction industry has become intense, as evidenced by the large numbers of contractor companies in various countries, which has pressured contractors to minimize costs as much as possible (Bayram, 2017). For the success of construction projects, the ability to deliver a quality product safely is vital (Loushine et al., 2006). According to Buniya et al. (2021), poor safety performance has been a severe challenge in the construction industry. Construction projects are increasingly becoming more complex, competitive and collaborative. Hence timely delivery is critical nowadays (Kerzner, 2022). Delays in construction projects often affect the overall performance of projects in areas such as profitability, efficiency and safety (Gunduz and Al-Naimi, 2022). By addressing the root causes of cost and time overruns and quality and safety challenges, performance will be improved, leading to the success of construction projects.

CONCLUSION

The performance of construction projects in Zimbabwe has been an issue, with most of them failing due to cost overruns, time overruns, quality concerns and safety challenges. This was conceptualized to solve the mentioned problems, which perpetrate waste (non-value adding activities) in Zimbabwe through LC. By applying TOC to construction projects, contractors can identify, understand, and remove constraints in operations to aid work progress. Therefore, this study presents the preliminary step of a doctoral study, which should culminate in guidelines that inform how TOC and LC will become change agents in construction in Zimbabwe. The research will further elicit responses from industry participants to answer the research questions and draw up recommendations for the main study.

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