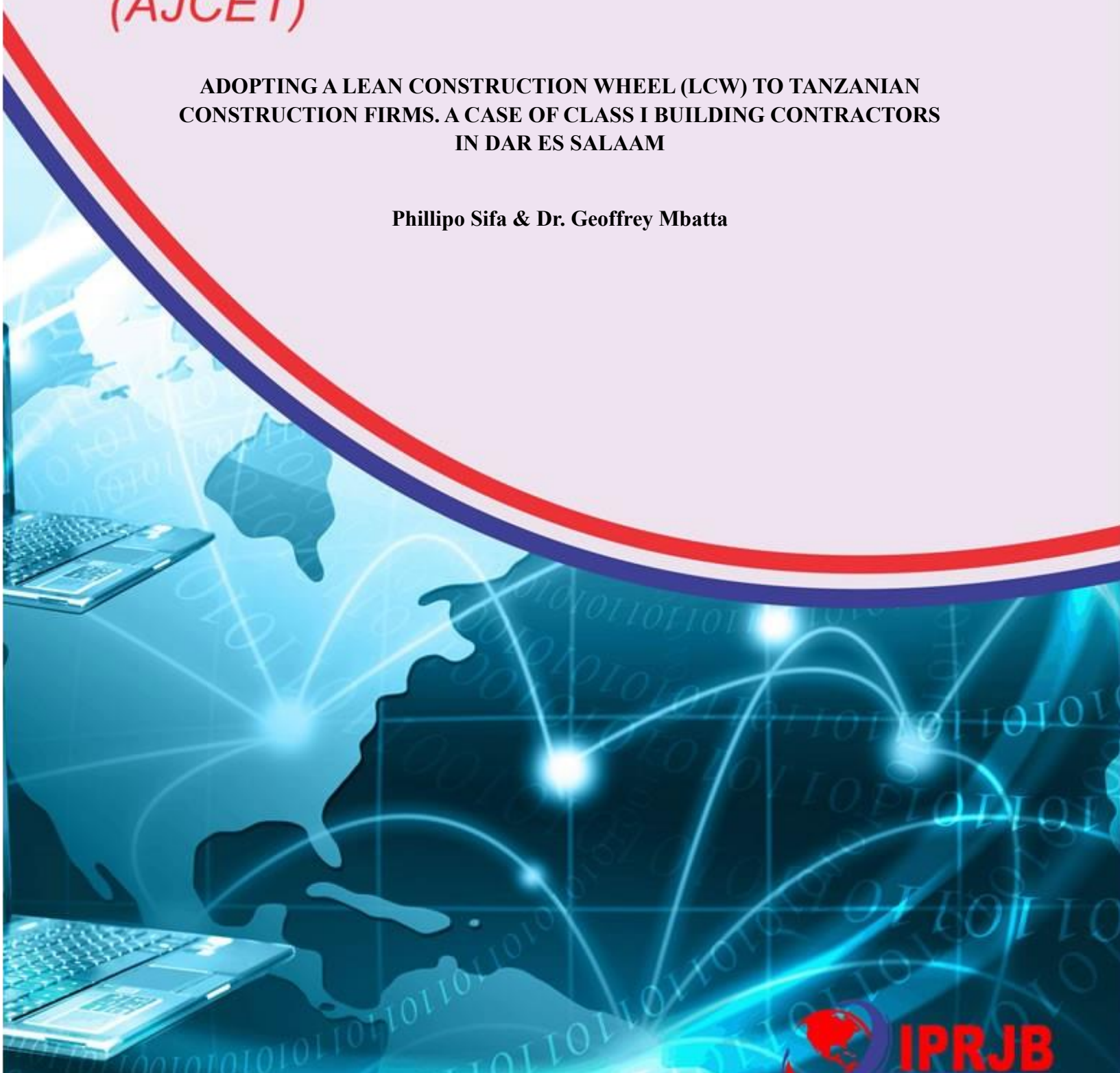


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**ADOPTING A LEAN CONSTRUCTION WHEEL (LCW) TO TANZANIAN
CONSTRUCTION FIRMS. A CASE OF CLASS I BUILDING CONTRACTORS
IN DAR ES SALAAM**

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**Adopting a Lean Construction Wheel
(LCW) to Tanzanian Construction Firms. A
Case of Class I Building Contractors in Dar
Es Salaam**

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Abstract

Purpose: This paper proposes a Lean Construction Wheel (LCW) to be a framework for Tanzanian construction firms. Absence of a lean construction framework brings failure into the implementation of lean construction, and this is attributed to a low level of awareness of lean construction.

Methodology: Quantitative research approach was used to assess the application of LCW principles by 57 Class 1 local building contractors located in Dar es Salaam. The results were analysed through the Statistical Package of Social Science (SPSS) were figured out.

Findings: The findings show that the term lean construction was found to be terminology to Tanzanian contractors, but still, they apply some of the lean construction principles.

Unique Contribution to Theory, Practice and Policy: The effect of the study will enhance the contractors to understand the importance of a lean construction framework and will encourage them to opt for the LCW framework. It will also create an urge to develop more frameworks that are better off for the Tanzanian construction industry.

Keywords: *Construction Management, Lean Construction, Lean Construction Wheel*

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INTRODUCTION

The construction sector is a key for developing other sectors; Tanzania has recently benefited from economic growth due to infrastructure construction. In the year 2020, the country witnessed a move from low income to a middle-income state. This shift in economic development was attributed to the construction and improvement of infrastructural facilities. Though the construction sector is important for economic development, it is characterized by challenges that affect product delivery and output. These problems are cost overruns, construction delays, quality problems, disputes and litigations (Ellis, 1993; Shurrab & Hussain, 2018; Aziz & Hafez, 2013; Singh & Singh, 2012).

Improvement in technology alone has not proved to be the solution for such problems. But a new management concept known as Lean Construction, together with the improvement in technology, offers a great solution for such problems (Kasiramkumar & Indhu, 2016). To practice this new management concept of lean construction, a framework in place has to be adopted. This framework is known as the lean construction framework.

Lean Construction (LC) was originated from the manufacturing industry, where it was termed lean production (LPN) (Koskela, 1992). LPN started in the 1950s in Japan in the automobile industry known as Toyota, where they used a smaller amount of everything, including fewer hominoid exertions, working place, production time, and many more (Koskela, 1992; Aziz & Hafez, 2013). In the 1980s, other industries started to apply lean production after seeing the Toyota Company's great achievements attributed to lean production (Liker, 2004; Gao & Low, 2014). The technological change did not cause these achievements but changed a new manufacturing philosophy known as Lean Production (Koskela, 1993).

One of the innovations for construction management is lean construction, and it has ways to change the mindset of people on how to manage construction projects. Lean construction came with the best solution for project cost overrun, delays and quality problems (Kasiramkumar & Indhu, 2016). Koskela, Howell, Ballard and Tommelein (2002) define lean construction as "a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value" (p.211). This means lean construction's core subject is waste eradication and value maximization (Ohno, 1988).

Since the discovery of lean construction back in the 1990's, many researchers came up with various frameworks for lean construction, some of which were successful and others were not. Some of these construction frameworks are the rapid lean construction-quality rating

model, Lean Construction Wheel (LCW) or lean conformance model, lean construction concept model, and lean construction maturity model (Bajjou, Chafi, & Ennadi, 2019). The main objectives of this research is to assess the application of the LCW framework in the Tanzanian construction firms and to propose areas for improvements in the construction industry for smooth adoption of the LCW framework in the Tanzanian construction firms.

LITERATURE REVIEW

Lean Construction Wheel (LCW)

Lean Construction Wheel (LCW) is a lean construction framework that was developed by researchers in the USA who were dealing with the improvement of the construction industry. They conducted some studies on construction firms through observation and questionnaires and came up with a set of principles crucial to implementing lean construction.

LCW was originated from the ‘lean wheel’, which was first established in the automobile manufacturing industry (Tapping & Luyster, 2002). This lean wheel is an important tool to measure lean conformance in an organisation (Diekmann *et al.*, 2004). The adoption of the lean wheel to the construction industry was meant to help organisations identify best practices of lean construction and aid them to assess themselves to the compliance of the lean concepts. The Lean Construction Wheel consists of five main parameters or principles. These principles are customer attention, waste elimination, workplace organisation, culture or people and unceasing advancements.

Application of LCW: Case of Other Countries

Few countries have applied this framework. One of the significances of this framework (LCW) is that it guides construction experts to adhere to the lean principles, and also it allows them to measure their application level or conformance level to lean principles. It helps an organisation to become lean. The following are the applications of LCW in different countries where the framework is used:

USA (2000)

The USA was the first country to measure the lean construction application level using LCW. In fact, LCW was developed through an intensive study that involved construction experts in the USA. Therefore, LCW became a base to measure the application level of lean construction to several organizations or construction firms. The following are the applications of LCW principles in the USA, as pointed out by Diekmann *et al.* (2004):

Customer Focus

The research indicated that there was low communication between the construction team

and the client; also, the contractors were not much aware of who the client really was. The value-adding activities were not clearly identified. But for the few early adopters of lean construction, there were some alternative ways to meet their customers' needs. They incorporated target costing and value engineering and emphasized the design-build delivery system to enhance client and contractor communication.

Culture/People

The training was only for a specific type of job; training on lean practices was not provided to a large extent. Workers were motivated to bring innovative ideas as one of the lean practices. Also, people in the organisation felt the need for improvements. Firms that had already started lean practices made compulsory training sessions on lean philosophy.

Workplace Organization/Standardization

Construction firms inspired their workers to be neat and organized at the construction site, though these regulations were not always adhered to. Visual aids were lowly applied. It was recommended that visual aids should be used to encourage cleanliness and proper organisation at the construction site.

Waste Elimination

Balancing the crew sizes and minimizing workers, equipment, and material movement were among the challenges the framework could face; however, there were more possibilities to change the situation. Also, it was alerted that some designs made construction more difficult unnecessarily.

Continuous Improvements

One of the most applied sub principles under this category was keeping the lesson learned file. It was recommended that during design, constructability reviews should be conducted to optimize the design and also to enable error-proofing.

Turkey (2011)

The average applicability of LCW principles was 72.35%; however, 95% of the contractors were not aware of lean construction (Algan and Nielsen, 2013). This is because some principles were applied unknowingly that they were lean principles. The main principles of customer focus and culture/people had low application compared to other principles. Training on employees was less, no time to listen to their ideas (employees), and low commitment level at work. These are important aspects of lean principles because lean has two important parts: social and process factors. Both of the two factors are very important. Focusing on process and ignoring the social factor can make lean never to be achieved.

Jordan (2014)

In their research, Sweis *et al.* (2016) indicated that customer focus, especially on meeting client requirements, was highly practised in Jordanian contractors. The Jordanian construction industry provides a picture of most construction industries in developing countries. Sweis and his colleagues' study shows that there was a strong relationship among contractors, suppliers, and subcontractors in Jordan.

Their research targeted the first-grade contractors (class 1); however, results showed that most contractors did not conform to the LCW principles. Employee empowerment, management commitment, and training on employees were very low. Other main LCW principles such as workplace organisation, waste elimination, and continuous improvements are applied but not satisfactorily.

Adoption of LCW

The adoption of the LCW framework depends on the applicability of its principles. If the principles are applicable to an organisation, then adoption is possible. However, some things need to be improved for the smooth adoption of this LCW. These areas are: Philosophy, Process, People and Partner, as well as problem-solving. These things are regarded as areas of improvement for easy or smooth adoption of LCW.

Areas of Improvement for smooth adoption of LCW

Lean Production or Toyota production system (TPS), where lean concepts originated, has four focusing areas known as "THE TOYOTA WAY MODEL" which provides techniques for production using lean tools and principles. These areas are termed as 4P (philosophy, process, people and partner, problem-solving) (Gao & Low, 2014). Since lean construction originated from the Toyota production system, it is important to focus on the areas verified as most effective in implementing lean production.

Therefore, any country that is starting to adopt the lean concepts in their construction industry should consider these areas to establish a solid basis to lean construction. Each area has sub-elements that can be explained in the context of construction, showing how lean can be adopted, practised or implemented.

METHODOLOGY

This paper aimed at assessing the application of LCW framework, where LCW principles were examined. The proper method for examining level of application of lean principles were to let the respondents rate their level of application by filling out of questionnaires. A quantitative research approach was used where the questionnaires distributed required some quantitative measures in answering them. For example, the application of lean

principles, 1 – (never), 2 – (very rare), 3 – (rare), 4 – (frequently), 5 – (very frequently) were used in the study. A qualitative research approach was also applied in this study. Specific objective (ii) falls on both quantitative and qualitative approaches as it requires opinions and suggestions from respondents, thus making them fall in the qualitative nature of the study.

Population in the research context are the components fitting to the group of concentration (Deb et al., 2019). In this study, the population of interest are building contractors' class 1. This research opted for class 1 because they are stable in terms of management and finance thus, they can accommodate any new management approach or strategy. The main respondents were Quantity surveyors, Engineers, and Management personnel. This selection technique is known as purposive sampling. It is a sampling technique where the choice of sample depends on the researcher's reasoning on who can best provide an appropriate answer to fit the research objectives (Kombo & Tromp, 2006).

The sample size for this study is all Class I local building contractors found in the Dar es Salaam Region. According to data from Contractors' Registration Board in Tanzania (CRB), the total number of class I local building contractors in Dar es Salaam is 57. That made questionnaires be distributed to all class I local building contractors, and main respondents were either quantity surveyors, engineers or construction managers.

Questionnaires had three main parts, part 1 for the introduction, part 2 for general information and part 3 for study objective. Part 3 had two sections, section I for assessing the application of LCW principles and section II for areas of improvements for smooth adoption of LCW. The general number of distributed questionnaires were 57.

For validation purpose, the questionnaires were first distributed as a pilot study to the required sample in order to see whether the terms used are logically and professionally understood. Thereafter, the questionnaires were modified and distributed to the respondents. The respondents required to fill the forms were professional experts, i.e., quantity surveyors, engineers, architects, and the management staff who have 5 years and above experience in construction. As Jack (2008) argues, if the percent of returned questionnaire reaches 60%, then the data is satisfactory or valid. The last phase in validation of questionnaires was concluded by statistical analysis of each response.

FINDINGS

A total of 57 questionnaires were distributed, and the returned questionnaire forms were 50, thus making the response rate to be 87.7%. Jack (2008) suggests that the expected response rate in research should be 60% for most research, but the expected response rate should be more than 80% for medical and pharmaceutical research. Thus, for this research,

the response rate is reasonably acceptable. The results show that 30% were quantity surveyors, 36% were engineers, and 34% were management teams. The three groups have a slight balance as they all range in $30\% \leq \text{range} < 40\%$. This means that the information did not base on either group.

The results also show the years of experience of the respondents. 46% of the respondents have 10-15 years of experience, 30% have experience of over 15 years, and 24% have 5-10 years' experience in construction. The lowest category in the experience of construction works was the 5-10 years group. This means many respondents have experience of 10 years and above in the construction industry. Testing data reliability is important because it shows that other researchers and other research beneficiaries can depend upon data. By the use of Cronbach's Alpha scale, the data collected for this research had the coefficient of 0.86. This guarantees that the findings of this research are reliable; thus, one can depend on this information.

Application of LCW Principles in Tanzanian Construction Firms

Table 1 indicates the Mean Score (MS) value comparison table which is used to interpret the level of application for each principle of the LCW.

Table 1: Mean Score Values (M) Comparison Table

	Mean Score Range	Color	Mean score	Interpretation
1	$3.90 \leq M \leq 4.23$	Yellow	High	High Applied
2	$3.56 \leq M \leq 3.89$	Blue	Medium	Low Applied
3	$3.22 \leq M \leq 3.55$	Red	Low	Very Low Applied

Table 2 shows the percentage of application, mean scores and ranking of these principles. All principles were ranked according to their level of application shown in the Mean score value. The first three most applied principles were “ensure management commitment”, “reduce double handling, workers and equipment movements”, and “consumers and client desires are met”. The least applied principles were “use of last planner system”, “teams are trained to multitask” and “provide training at every level”.

The general applications for all principles are as follows; the Very frequent application was 19.62%, frequent application was 43.62%, and rare application was 36.76%. Considering the two, very frequent application and frequent application, the general application of LCW is 63.24%. Among all 21 LCW principle that were listed, there is no any principle that was rated as a very rarely or never applied. That shows that the LCW principles are applied by most of the respondents but the applied level is still low.

Table 2: Application of LCW Principles in Tanzanian Construction Firms

(Key: VF=Very frequently, F=Frequently, R=Rare, VR= Very Rare, NVR= Never applied, M.S= Mean Score)

No	Application of Lean principles	%					M.S	RANK
		VF	F	R	VR	NVR		
Attention to Client & Consumer								
1	Consumers & Client desires are met.	34%	44%	22%	0	0	4.12	3
2	Value is demarcated in the perspective of the client/consumer.	10%	48%	42%	0	0	3.68	17
3	Meet the alternating needs of the client.	22%	48%	30%	0	0	3.92	8
4	Teams are trained to multitask	10%	36%	54%	0	0	3.56	20
5	Practice budget estimation and VE	22%	40%	38%	0	0	3.84	10
Culture/People								
6	Provide training at every level	0	22%	78%	0	0	3.22	21
7	Encourage employee empowerment	20%	52%	28%	0	0	3.92	9
8	Ensure management commitment	32%	58%	10%	0	0	4.22	1
9	Collaborating with suppliers and sub-contractors	26%	46%	28%	0	0	3.98	7
Workplace Organization								
10	5S's is practiced to organize workplace	24%	54%	22%	0	0	4.02	6
11	Implement error-proofing devices	0	68%	32%	0	0	3.68	18
12	Provide visual management devices	12%	48%	40%	0	0	3.72	14
13	provide logistic of materials	14%	42%	44%	0	0	3.7	16
Waste Elimination								
14	Reduce double handling, worker and equipment movement.	26%	62%	12%	0	0	4.14	2

Table 2: Application of LCW Principles in Tanzanian Construction Firms

15	Balance teams, match flows	10%	50%	40%	0	0	3.7	15
16	Delivery of materials on time and right quantity	38%	34%	28%	0	0	4.1	4
17	Institute JIT delivery, supply chain management	18%	36%	46%	0	0	3.72	13
18	use of last planner system	20%	26%	54%	0	0	3.66	19
Continuous Improvement								
19	Make use of lessons learnt and root cause analysis	16%	42%	42%	0	0	3.74	12
20	Create a standard response to defects	32%	38%	30%	0	0	4.02	5
21	Inspire teams to nurture accountability for quality	26%	22%	52%	0	0	3.74	11
	Average % of general application	19.6%	43.6%	36.7%	0	0		

Areas of Improvement for Smooth Adoption of LCW in Tanzanian Construction Firms

The results show the following to be areas that need to be improved to adopt the LCW framework. These areas were K1 = Management, K2 = Process, K3 = Training, K4 = Motivation to workers, K5 = Relationship between management and workers, K6 = Reducing work overload, K7 = Avoid accumulation of errors, K8 = Focus on waste elimination.

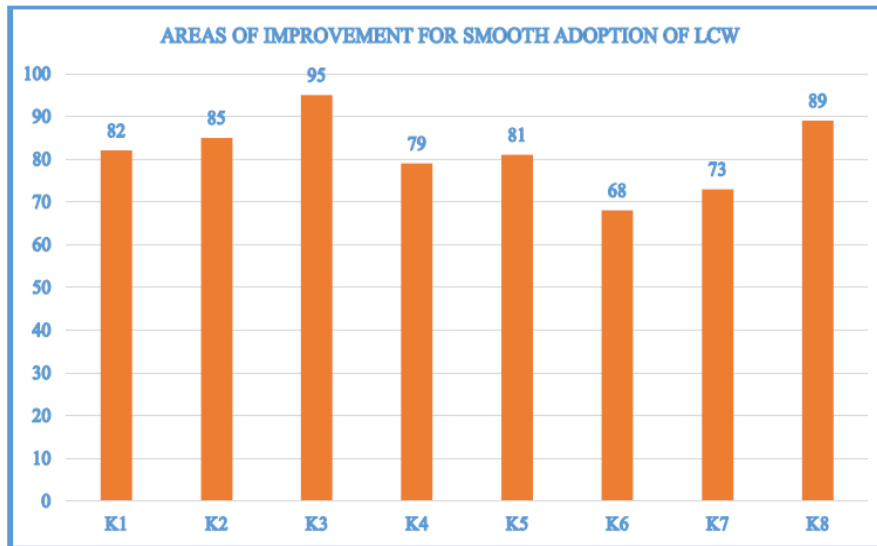


Figure 1: Areas of Improvement for Smooth Adoption of LCW Framework in Tanzanian Construction Firms

Figure 1 indicates the areas of improvement for smooth adoption of the LCW framework. The training was highly recommended by 95%, followed by a focus on waste elimination 89%, Process 85%, Management 82%, Relationship between management and workers 81%, Motivation to workers 79%, Avoid accumulation of errors 73%, and Reduce work overload 68%.

Discussion

The application of LCW principles involved 21 principles grouped into 5 main principles: attention to client, culture or people, workplace organisation, waste elimination and continuous or unceasing improvements. The 21 principles were ranked using the mean score values. The 5 main principles were also ranked considering the mean scores of each sub principle. Waste elimination was first ranked, indicating that it was highly practised. Though waste elimination is given the first position in its application, the problems that arise due to construction wastes (delays, cost overruns) still exist. This is because the application level of waste elimination is not adequate.

The second-ranked of the main principle was culture or people. The sub principles under culture or people which mainly were applied are “*ensure management commitment*”. Other sub principles were “*collaborating with suppliers and subcontractors*” and “*ensure employee empowerment.*” The sub principle with the least application was “*Provide training at every level.*”

To raise an awareness of lean construction, training is very important. Regular training is required at all levels of staff in the organisation or construction firm. Management should be well trained and become experts on lean. Employees should be trained in a lean philosophy and lean techniques (Warcup, 2015). Low awareness of lean construction was also observed in the Turkey construction industry (Algan & Nielsen, 2013), where lean construction was a terminology. The training was suggested to spread awareness of lean to the construction industry.

Continuous improvement was the third-ranked main principle. Under continuous improvements with the high application, the sub principle was *“creating a standard response to defects.”* This means contractors should have a plan on what to do when the defects are discovered. *“Inspire the team to nurture accountability for quality”* and *“Make use of lessons learned and root cause analysis”* were less practised. If the team does not have a sense of accountability for quality, many reworked and additional costs (Sweis et al., 2016). Construction firms should never be satisfied with their application level; they should always seek improvement a room to grow.

The fourth-ranked main principle was *“Attention to customer or client.”* Although it was less practised, it should be given priority simply because the customer owns the project, he/she pays for everything required for the project. He/she is the one with a vision regarding the project; therefore, his/her wishes must be well understood by the contractor and even the consultant team so as to deliver what is required by the client (making the client dream into reality). The most applied sub principles under this are *“clients and consumers’ desires are met”* and *“meeting the alternating needs of a client.”* The less practised sub principle is *“teams are trained to multitask.”*

Understanding clients' needs is one thing and to meet that need is another thing. The contractor needs to apply other principles to meet the client requirements. In the Jordan construction industry, *“attention to customer or clients”* is the first and most applied principle among the 5 main principles of LCW (Sweis et al., 2016). That did not make it successful because other principles are less applied. To successfully implement lean construction, all principles should have a full application and equal application.

The last ranked main principle was workplace organisation. The most applied sub principle under workplace organisation was the *“Use of 5S’s to organize the workplace.”* This principle is important because it saves time that could be used to look at misplaced tools or equipment; it helps avoid accidents and injuries. Other sub principles, such as *“Implementing error-proofing devices”* and *“Provide visual management devices”*, were less applied. The application of all sub principles requires to be improved so as to attain lean construction.

The first specific objective of this study answers the question of applicability of the LCW framework in Tanzanian construction firms. As shown in Table 2, the general application of LCW principles is 19.62% very frequent, 43.62% frequent and 36.76% rare. This makes the total (frequent application) 63.24%, adding up 19.62% and 43.62%. 63.24% is above 50%. Diekmann *et al.* (2004) rated 50% of lean principles' applicability level to be fair; and below 50%, the framework is not applicable. For that reason, according to this research, the LCW framework is APPLICABLE to the Tanzanian construction firms; therefore, it can be ADOPTED and has to be adopted.

The adoption of the LCW framework will enhance the application of lean construction in Tanzanian construction firms. This research has identified eight areas of improvement for the smooth adoption of the LCW framework. These eight areas could simply be absorbed in the Toyota Way Model, which has four main principles 4P (philosophy, process, people and problem solving) on which researchers suggest that these four principles could be focusing areas of improvements for smooth adoption of the LCW framework in the Tanzanian construction firms. Table 3 shows how the proposed areas of improvements can be immersed in a Toyota Way Modal.

Table 3: Proposed Areas of Improvement for Smooth Adoption of LCW Framework Categorized in a Toyota Way Modal

No	Proposed areas for improvement for smooth adoption of LCW framework	Category under 4P(Toyota Way Modal)
1	Focus on waste elimination	Philosophy
2	Process	Process
3	Reducing work overload	
4	Management	People
5	Training	
6	Motivation for workers	
7	Relationship between management and workers	
8	Avoid accumulation of errors	Problem Solving

CONCLUSION AND RECOMMENDATIONS

The study has observed that the Tanzanian construction firms do not have a lean construction framework. Therefore, it has proposed the LCW framework to be used. The adoption of the LCW framework could enhance the implementation of lean construction. The proposed areas of improvement have a significant role to play in the adoption of the framework.

The study also found out that the LCW framework is applicable to Tanzanian construction

firms. It could probably be applied to the construction industry as a whole. If the framework is applicable, then the question of adoption is simple. What is required is how it can be adopted. The adoption will be much easier when dealing with areas for improvement. This study will help other countries that are new to the lean philosophy and beginners of lean construction to adopt the LCW framework or develop a framework to guide them in complying with lean concepts. The study will also enlighten the contractors to embrace changes. Since there are new ways to manage construction projects, they should not be reluctant by sticking with old ways (conventional methods). The study expects that contractors will have a lean construction framework in their organizations. According to the research findings and discussion, the researcher recommends the following.

Training

Training is not sufficiently provided to raise lean awareness among construction workers. Regular training should be provided. Contractors should seek to train their employees, and the training should target all levels of the management in the organisation and to the workers as well. Professional organizations such as Contractor Registration Board (CRB), AQRB, and ERB should also figure out how to introduce Lean Construction to the construction industry by first conducting seminars, debates, and lean construction research by providing site training.

Lean Experts

There should be Lean experts in every field of production not only in construction industry. Lean experts should be ready to offer lean consultancy services to construction firms that want to move to a new (lean) management approach.

Lean Framework

The lean framework should be mandatory for any construction firm. Every firm should have a lean construction framework to make sure that they conform to lean principles. This research provide a base for further research on lean construction in particular and for Tanzanian context. This paper will help the construction experts to get this lean principles to practice. This paper can also be used for academic purpose in teaching so that this lean construction knowledge could be immersed to many young construction professionals. The impact of this paper will enhance quick project delivery, quality work and cost effectiveness which in turn is the value for money for such projects. The researcher suggests an area for further study to be “Evaluation of lean construction tools in the Tanzanian construction projects.” Lean construction has got some tools that enable its implementation. Some of the tools are JIT, IV, Error-proofing, and Last planner.

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