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THE IMPACT OF LEAN CONSTRUCTION TOOLS ON THE REDUCTION OF CONTRACTOR-RELATED CAUSES OF DELAY IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Though lean construction is abundantly used in other countries, it is an underrated concept when it comes to Sri Lanka. Past research studies collectively demonstrate that construction industry in Sri Lankan is lagging in the effective implementation of lean in construction processes. Demonstrating the effectiveness of the lean construction tools to mitigate causes of delay will be a future research concern. Since, delays are still taking place within Sri Lanka, it is crucial to look at how lean construction tools can affect to reduce construction delays. This paper aims to identify the impact of Lean Construction Tools (5S, Last Planner System, Visual Management, First Run Studies) on reduction of Contractor related causes of delay. This was met by utilizing a mixed research methodology, which includes both the gathering of quantitative data through a questionnaire survey and the gathering of qualitative data by conducting semi-structured interviews with construction industry specialists. SPSS software was used to analyze data collected from the questionnaire survey, and content analysis was used to examine data obtained from the semi-structured interviews. The results revealed that implementation of Lean Construction Tools can lead to reduction of Contractor related causes of delay. Further, it was disclosed that 5S is the Lean Tool that has the highest impact on reduction of Contractor related delays. Findings have also revealed that lack of awareness about Lean Construction is the most critical challenge for successful implementation of Lean Construction Tools within Sri Lanka. The results depict that in order to overcome this barrier awareness on Lean Construction must be enhanced among construction industry professionals.

KEYWORDS: *Lean Construction Tools, Contractor Related Causes Of Delay, Construction Industry, Sri Lanka*

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1. INTRODUCTION

In construction, delay is the period of time that elapses after the completion date specified in the contract and as mutually agreed upon by the contract's parties. Delay is one of the most reoccurring issues in the construction sector around the world. Contractor is the party that is mostly responsible for construction delays (Farooqui, 2007). In Sri Lanka, the majority of construction projects are prone to delays and timely completion is typically rare. Although there are delay mitigation strategies, they are not effectively used in Sri Lankan construction industry (Jayalath, 2010).

The foundation for this lean approach is decreasing waste throughout the process and attempting to make tasks as simple to comprehend, initiate, and manage as feasible is the basic concept behind the term "Lean". (Ansah, 2016). Lean construction tools are designed to improve project performance by eliminating waste and increasing project value. It aids in increasing productivity, minimizing time and ultimately increasing client satisfaction (Akinradewo, 2018).

Countries such as UK, USA and Singapore have achieved sustainable benefits by implementing lean construction, and it is the best time for the Sri Lankan construction industry to consider about implementing lean construction in order to improve overall performance (Thilakarathna & Senaratne, 2012). Since lean construction tools have proved their effectiveness over the past years, and project delay is a common problem every Sri Lankan construction project faces, instead of dealing with causes of delay, an effort should be taken to facilitate the timely delivery of future construction projects in Sri Lanka (Thilakarathna & Senaratne, 2012). Gomez-Cabrera (2020) has established that lean construction tools can be assigned to mitigate factors contributing to delay and has further emphasized that more than one lean tool can be used to reduce the effect of a single factor.

Adapting a large number of lean construction tools at once is not practicable and the purpose of all lean tools is not reducing time overrun. Therefore, 4 lean construction tools which can be adapted in order to mitigate delays have been chosen for the study. Since Contractor is the party that is mostly responsible for construction delays, this paper addresses mitigating causes of delay over which the Contractor has control by adapting lean construction tools.

A: Contractor Related Causes of Delay

A research conducted on construction project delays in Florida State in USA by Sayad (2002) shows that various stakeholders are responsible for the overall project delay in the following ways; Contractor = 44%, Owner = 24%, Government = 14%, Shared (between Owner & Contractor) = 12% and Consultant = 6%.

A study carried out by Farooqui (2007) on delays within Pakistan construction industry depicts that several stakeholders are accountable for the entire project delay in the following manner; Contractor = 48.75%, Consultant = 17.5%, Owner = 16.25%, Government = 8.75%, Shared = 8.75%.

According to above researches, it is obvious that Contractor is the party that is mostly responsible for construction delays. Therefore, taking an endeavour on mitigation of Contractor related delays can significantly effect on reducing construction delays.

There are many research studies conducted in different countries in order to identify Contractor related causes of delay. Poor site management, poor communication and coordination and ineffective project planning are the common causes for Contractor related delay in Indian construction industry (Das & Emuze, 2017). According to a research done in Sri Lanka by Kesavan (2015) it was highlighted that ineffective project planning and scheduling is the most prominent cause for Contractor related delays in construction industry in Sri Lanka.

A research done in Malaysia, Yap (2021) has established that rework due to errors in construction and low productivity of labour are among the most common causes of Contractor related causes of delay

in Malaysian construction industry. Rework due to errors in construction is the most significant cause of delays attributable to Contractors in Sri Lankan construction industry (Jayasinghe, 2019).

According to Ibironke (2013) resource shortage and inadequate cash flow management are the common causes for Contractor related causes of delay in Nigerian construction industry. Sivarajah (2021) highlighted that due to the current economic crisis in Sri Lanka, resource shortage (material, labour, machinery and equipment) is the most common reason for Contractor's inability to complete the project within agreed period of time.

B: Contractor Related Delay Mitigation Strategies

Tharsan (2020) has mentioned that the majority of earlier studies revealed measures to mitigate delays in the construction industry, but they are common strategies, and further he has identified 15 applicable mitigation strategies in the Sri Lankan construction context to mitigate contractor's causes of delays. Dolage (2015) has identified 10 mitigation measures and Kesavan (2015) has established 7 delay mitigation strategies to mitigate Contractor related delays that occur in Sri Lankan construction industry.

According to above mentioned literature, identified delay mitigation strategies to mitigate Contractor related delay are; effective project planning and scheduling, maintaining positive financial stability, well qualified and experienced professionals and staff, risk analysis and management, selection of suitable Sub-Contractor, effective site management and supervision, collaborative working environment in construction, proper material procurement, continuous monitoring of construction site and effective human resource management.

C: Lean Construction Tools that Can be Adapted to Mitigate Contractor Related Causes of Delay

Lean construction tools attempt to improve delivery systems and procedures by eliminating waste, promoting productivity, enhancing health and safety and satisfying customer expectations (Anash, 2016).

1) 5S: **5S** is a fundamental lean tool to maintain work flow efficiently. The 5S process consists of five steps that can assist a workplace get rid of waste and improve process efficiency. The 5 S's of lean are Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke) (Salem, 2014).

The principal component of 5S is 'Sort' (Organizing). Simply, it is the efficient use of the available space. Sort can be advantageous in reducing the searching time for a material/document. The main aim of Set in order of 5S is to provide an efficient workspace by defining a designated storage area. It helps in preventing material and document mismanagement. Shine in 5S signifies cleaning. It contains a thorough examination of the workplace, increased cleanliness and the creation of an ideal working environment for employees. Standardize means creating a consistent approach for performing tasks and procedures by establishing the procedure for maintaining the first three pillars. Sustain implies maintaining & implementing all 4 components mentioned above and making it a practice to follow and maintain appropriate processes (Ghule, 2020).

2) Last Planner System*:* The Last Planner System (LPS) is the most well-known tool in lean construction (Akinradewo, 2018). LPS is a planning method, and it helps to reduce workflow unpredictability. Porwal (2014) has identified that pros of LPS are improved construction planning, better site management, better communication and greater collaboration amongst the stakeholders.

The LPS has five steps in its planning process: master scheduling, phase scheduling (pull planning), look ahead planning, weekly work planning and percentage plan complete (PPC). Master schedule is the complete project timetable with milestones. The phase schedule which is developed by the teams working on every phase, is more informative when compared to the master schedule. It must be ready at least six weeks before the number one activity (Akinradewo, 2018). Look ahead plan organizes the workflow in the best

possible order. Weekly work plan meetings address quality concerns, safety concerns, the weekly schedule, material demand and construction procedures. PPC assesses the number of the team's weekly assignments that are finished on time (Porwal, 2010).

3) Visual Management: The primary goals of visual management are to promote the widespread flow of information within the workplace and to reduce obstacles to that circulation of information. By providing access to information to all project stakeholders, visual management increases organizational transparency. It presents information via visual signs rather than words, making it easier for all project stakeholders to understand (Singh, 2021).

Visual management boards with all the pertinent information updated are kept in the centre of the workplace. Numerous visual management methods and tools are available such as organizational chart, gantt chart, value stream maps, kanban boards and project performance chart (Tezel, 2017). One of the most crucial concepts in visual management is the "Big Room," where all project related information is exhibited via display boards, diagrams, and colour coding (Singh, 2021). Every day construction professionals gather for a daily meeting which is around 15 minute meeting in the big room, where they use various visual tools on display to address issues present at the site.

4) First Run Studies: A first run study is a trial execution of a procedure with the aim of determining the most appropriate methods, strategies and sequencing for the process to be carried out. They are applied to redesign crucial assignments (Salem, 2005). It is a part of the effort to continuously improve; these attempts consist of productivity studies and work method reviews by restructuring and simplifying the various tasks involved. These studies frequently use photos, video clips, and graphics (3D illustration) to demonstrate a process or provide work instructions (Alarcon, 1997). The assignment chosen for the first run study should be thoroughly explored, offering recommendations and ideas to examine alternate methodologies for carrying out the activity. A PDCA cycle (Plan, Do, Check, Act) is recommended to develop the study (Alarcon, 1997). The objective is to carefully plan and investigate first runs of crucial tasks, using previous studies as a guide and developing standard work procedure designs for the project. The cost, errors, and accidents are reduced because of this experimental strategy, which develops a tested method that all crews can learn. It will be simple to test out new work process designs, new technology and tools, as well as various crew combinations, etc. once these studies become a routine part of the organization (Alarcon, 1997). A key component of first run studies is the integration of all performance criteria into work process design, with safety being prioritized over quality, time, and cost. That can be planed and analyzed for actual results to distinguish between plan quality and plan execution defects, allowing each to be addressed and improved.

2. METHODOLOGY

The research study is targeted to identify the impact of lean construction tools on reduction of Contractor related causes of delay in construction industry in Sri Lanka. The entire research was appraised through questionnaire surveys and interviews held among construction industry professionals in Sri Lanka. This was a combination of both qualitative (interviews) and quantitative (questionnaire survey) analysis.

A; Data Collection Methods

A detailed questionnaire was circulated across the professional groups within the Sri Lankan construction sector. A web based questionnaire (Google form) was designed and distributed via e-mail and social media among construction industry professionals actively employed in the industry. The respondents were asked to rank the different viewpoints according to a “Likert Scale”. The questionnaire was distributed among 40 number of professionals (selected through stratified random sampling method) from various disciplines including Project Managers, Construction Managers, Engineers, Quantity Surveyors and Architects because based on

the perspective of different people the answers to the questions may vary due to their thinking capacity, knowledge and industry experience. Out of them, 35 responses were received, reflecting an 87.5% response rate.

To attain the aim of this study, semi structured interviews were conducted using open ended questions. The related areas can be broadly discussed by conducting semi structured interviews (Sadan, 2014). The interviewees were chosen by employing the purposive sampling method.

B. Conceptual Framework

The overall research methodology is based on this conceptual framework.

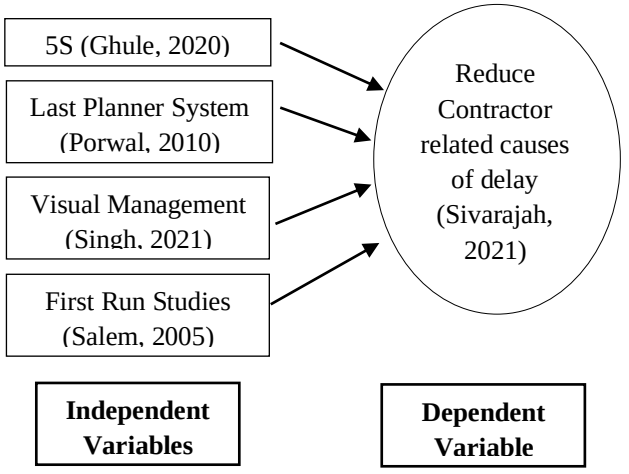

Figure 1: Conceptual Framework

Independent Variables (IV) are identified to determine the effect of each one of them against the Dependent Variable (DV) of the study. By considering the conceptual framework, assumptions were developed. For the purpose of examining the agreement among the respondents on reduction of Contractor related causes of delay by adapting lean construction tools, the hypotheses were developed as follows.

HA_1: There is a relationship between 5S and Reduce Contractor related causes of delay.

HB_1: There is a relationship between Last Planner System and Reduce Contractor related causes of delay.

HC_1: There is a relationship between Visual Management and Reduce Contractor related causes of delay.

HD_1: There is a relationship between First Run Studies and Reduce Contractor related causes of delay.

C. Data Analysis Methods

To check the hypotheses of the study, statistical data analysis was used. The establishment of the relationship between the independent and dependent variables was done through Correlation Analysis. The regression analysis was utilized to assess the influence or impact of the independent variables on dependent variable. This analysis was carried out using the SPSS software, which provides a diverse set of formulas and statistical techniques. Data obtained through semi structured interviews was analysed by using content analysis. Representation of data was done in the form of tables.

3. RESULTS AND DISCUSSION

It was investigated whether the professionals had experienced Contractor related delay. More than 90% of respondents had Contractor related delay on construction projects, highlighting it as a severe issue in the construction sector and the need for efforts to mitigate Contractor related delay in projects.

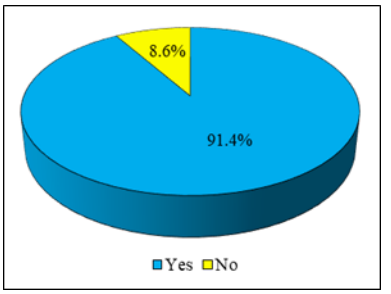

Figure 2: Experience in Contractor Related Delay

A: Correlation Analysis

The data obtained from questionnaire which was in the form of Likert scale were analyzed using SPSS

software to verify the relationship between the IV and DV.

The "Pearson Correlation Coefficient" was applied by using the SPSS software in this study because it offers an indicator of linear relationships between two variables that range from -1 to +1. When two variables are positively correlated, it implies that when one variable's value increases, value of the other variable also increases. When two variables are negatively correlated, it denotes that as one variable's value rises, the value of the other variable drops. Relying on the significance value (P), the correlation coefficient will be satisfied. If $P < 0.05$, the DV has a relationship with the particular IV and If $P \geq 0.05$, the DV does not have a relationship with particular IV.

Table 1: Correlation Analysis (SPSS Generated)

Correlations

		AVGA	AVGB	AVGC	AVGD	AVGE
AVGA	Pearson Correlation	1	.066	-.200	.047	.479**
	Sig. (2-tailed)		.707	.250	.790	.004
	N	35	35	35	35	35
AVGB	Pearson Correlation	.066	1	.037	-.169	.397*
	Sig. (2-tailed)	.707		.832	.333	.018
	N	35	35	35	35	35
AVGC	Pearson Correlation	-.200	.037	1	.274	.499**
	Sig. (2-tailed)	.250	.832		.111	.002
	N	35	35	35	35	35
AVGD	Pearson Correlation	.047	-.169	.274	1	.386*
	Sig. (2-tailed)	.790	.333	.111		.022
	N	35	35	35	35	35
AVGE	Pearson Correlation	.479**	.397*	.499**	.386*	1
	Sig. (2-tailed)	.004	.018	.002	.022	
	N	35	35	35	35	35

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Where,

N = No of Respondents
AVGA = Average of 5S
AVGB = Average of Last Planner System
AVGC = Average of Visual Management
AVGD = Average of First Run Studies
AVGE = Average of Reduce Contractor related causes of delay

Table 1 depicts the results of the correlation analysis. Since the Pearson correlation of all variables range from -1 to +1 and $P < 0.05$, it was proved that all the identified IV (5S, Last Planner System, Visual Management and First Run Studies) have a positive relationship with the DV (Reduce Contractor related causes of delay).

B. Regression Analysis

This was conducted in order to ascertain which independent variable has the maximum impact on the dependent variable. The identical set of data retrieved through questionnaire utilized for the correlation analysis were analyzed in regression analysis by using SPSS software.

Table 2: Model Summary of Regression Analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.884[a]	.782	.753	.161

a. Predictors: (Constant), AVGD, AVGA, AVGB, AVGC

The predicted R^2 of the model is displayed as 0.782. This value reflects the extent of relationship between lean construction tools and the reduction of Contractor-related causes of delay, and it is approximately 78.2%.

Table 3: Regression Analysis (SPSS Generated)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-.659	.515		-1.280	.210
	AVGA	.345	.056	.543	6.176	<.001
	AVGB	.340	.076	.390	4.470	<.001
	AVGC	.325	.058	.515	5.629	<.001
	AVGD	.215	.069	.285	3.133	.004

a. Dependent Variable: AVGE

The unstandardized β value or coefficients of the regression portray the percentage of reduction in Contractor related causes of delay (DV) reflected by lean construction tools (IV).

The relationship of the above regression model can be explained as mentioned below

$$Y = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + Std.E$$

Equation 1: Linear Regression

$$Y = -0.659 + (0.345*AVGA) + (0.340*AVGB) + (0.325*AVGC) + (0.215*AVGD) + Std.E$$

Equation 2: Linear regression (Based on SPSS generated data)

According to Table 3, it is depicted that the reduction of Contractor related causes of delay increases by 34.5% with the increase of properly implemented 5S, the reduction of Contractor related causes of delay increases by 34% with the increase of properly implemented Last Planner System, the reduction of Contractor related causes of delay increases by 32.5% with the increase of properly implemented Visual Management, and the reduction of Contractor related causes of delay increases by 21.5% with the increase of properly implemented First Run Studies.

4. CONCLUSION

The study was conducted to investigate the impact of lean construction tools on reduction of Contractor related causes of delay. As per the conducted Correlation Analysis, all the mentioned hypotheses were satisfied indicating that there is a positive relationship between lean construction tools and reduction of Contractor related causes of delay. According to the Regression Analysis, 5S is the lean tool that has the highest impact on reduction of Contractor related delays.

Through the interviews it was revealed that there are barriers to implement lean construction tools within the Sri Lankan context. Identified critical implementation barriers were lack of awareness on lean construction, lack of technical knowledge and initiative in industry professionals, reluctance to adapt to new methodology, lack of agreed implementation framework and lack of government support.

5. RECOMMENDATIONS

Conducting awareness programmes on lean construction, testing the lean construction tools for a short period project with professional staff, increasing team work and encouraging top level management of the company to implement lean construction tools within their company are short term recommendations to overcome implementation barriers of lean construction tools.

Providing proper education on lean construction, providing proper training on lean construction, designing a proper implementation framework, carrying out a case study to identify benefits of lean construction, establishing a government institute for lean construction in Sri Lanka and increasing implementation of new technology in construction industry are long term recommendations for successful implementation of lean construction tools within Sri Lanka.

Research Limitations

This research was limited to the delays in Sri Lankan construction industry and Contractor related causes of delay, and it was limited to the lean construction tools considered with delay. It was also limited to the lack of expertise available in the Sri Lankan context regarding lean construction, to the lack of knowledge of interviewees on lean construction, and to the lack of time availability. The proposed recommendations stated in this research are as per the opinion and experience of professionals in the industry.

Future Research Directions

In the future, one can develop a framework to implement lean construction tools within the Sri Lankan context. Further, one can engage in finding the impact of lean construction tools on reducing cost overrun of construction projects in Sri Lanka. One can undertake a case study on implementing lean construction tools as a solution to mitigate Contractor related causes of delay in the construction industry in Sri Lanka.

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