APPLICATION OF LEAN CONSTRUCTION PRINCIPLES AND PRACTICES TO ENHANCE THE CONSTRUCTION PERFORMANCE AND FLOW

Upeksha Hansini Madanayake*
School of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

Lean thinking has now become a radical philosophy that has permeated and expanded in to several sectors other than just manufacturing. The concept of Lean thinking evolves the optimization of work flow related functions and the possible outcomes with its contribution to sustainable construction. Correspondingly, application of lean theories and principles in to construction sector has the potential to improve the quality of work, aggravate the function related effectiveness, minimize the cost components/ waste and increase the overall profit in both strategic and operational levels. Apparently, it appears that the lean techniques have immensely contributed for many possible cost reductions compared with the traditional project management techniques. However, few barriers for the implementation of lean principles are also on the contrary. The research aims to investigate the effects of Lean Construction applications while identifying the prevailing barriers related to the same. The research has exploited qualitative methods to explore the aforementioned research question. This paper presents an exploratory study from extent literature, predominantly based on a case study of a project management organisation whereas the arguments were strengthened and underpinned by the formation of a conceptual framework to explore the contribution of implementing lean construction techniques in sustainable construction. The research findings would ultimately help different stakeholders on applying lean theories in to practice.

Keywords: *Integrated Project Delivery System; Last Planner; Lean Construction; Lean Manufacturing.*

1. INTRODUCTION

1.1. BACKGROUND AND RATIONAL

Construction industry in UK has the potential to improve its capabilities and efficiency by modernising the industry and increasing users' satisfaction (Egan, 1998). Furthermore, Egan (1998) suggests that Lean Construction (LC) is a way forward that enhances efficiency by smoothening the construction work flow while improving the overall value of a product to achieve the pre-determined goals, where ultimate users' satisfaction is successfully achieved (Marhani *et al.*, 2013). 'Value' is the competent formation of a service provided to the customer at the correct time, at a reasonable cost, in to the correct quality standards (Ballard and Howell, 1998). Lean thinking can also be defined as a goal that is set against a set of measurements of perfections (Diekmann and James, 1994). Perfection may not be attainable in a zero-defect/ zero-waste/ zero-carbon parameter. Nevertheless, it can be achieved in such a parameter where the construction environment represents a sustainable future where defects and wastes are utmost minimised that leads to eliminate cost overruns, delays and avoid inconsistency with the customer expectations (Gregory, 2011).

Lean thinking is constituted with a long history where manufacturing was the sector that lean thinking was initially applied. Over the last 10 years an increasing number of companies have implemented lean construction practices with an intention to improve performance in construction projects (Bertelsen, 2004). However, there is still a need to provide more extensive analysis of the empirical evidence available to assess the impact of the implementation[ii] of lean construction. This paper observes

* Corresponding Author: E-mail - u.madanayake@gmail.com

the applicability of lean construction theories and principles in to Sri Lankan construction practice. The implementation of Last Planner System is in-depth discovered while the impacts of implementation of lean construction techniques are analysed within the case study in to the Sri Lankan context. The paper also discusses difficulties and barriers for implementation, productivity improvements, variability reduction and effectiveness of implementation strategies. To recapitulate, recommendation is compiled with the lessons learned from the research for further improvements.

1.2. PROBLEM STATEMENT

Construction projects are common and well known for being delayed, over-budget and shrank with non-unique quality standards. Hither to, the traditional construction management methods has been successful for some extent in addressing the aforementioned common problems. Nevertheless, it appears that the effectiveness of conventional project management approaches still remain in a neutral-impassive status whereas most of the problems still remain same.

Sri Lankan construction industry is facing many challenges with the recent economic downturns and as well as recent major political revolt. Building and construction sector in Sri Lanka is one of the major sectors that directly effects with the track of Gross Domestic Product (GDP) growth rate. As reported by the Department of Census and Statistics - Sri Lanka, the current (2015 first quarter) GDP in Sri Lanka has declined to 6.40% from 7.7% in the fourth quarter of 2014.

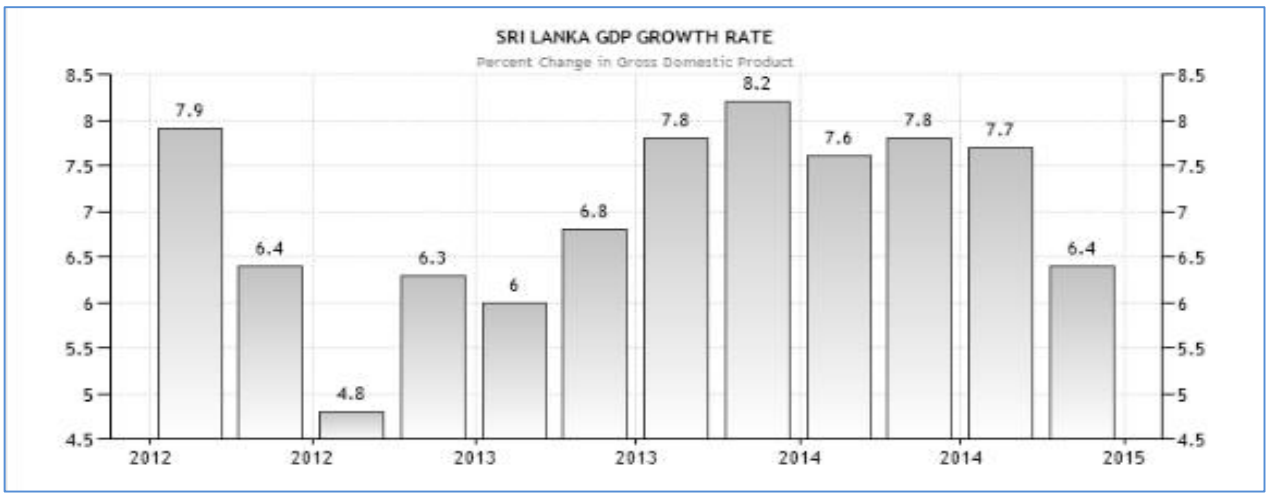


Figure 1: GDP Growth Rate, Sri Lanka (2012-2015)
Source: Department of Senses and Statistics, Sri Lanka (2015)

Due to the instability of the economy which is originated through political revolutions and improper systems, construction industry in Sri Lanka was suffering all through the time. However, despite the economic boom, Sri Lanka was able to withstand with many city development projects as well. Infrastructure, hospital, urban development, town and country planning, hotel and apartment projects were under taking despite this economic boom. Considering the decline of the GDP growth rate and the upturn of inflation, it seems that the unemployment within the country is accumulating in a notable rate. Government policies and strategies, investments, competencies of in-house organisations, foreign aids which are due, available resources and potentiality of getting maximum out of it, sustainable approaches are few of the main factors that determine the way forward of the economy of the country (Central Bank of Sri Lanka, 2015). Filtering in to the construction sector, the construction cost factor is highly determined by some aspects such as labour, materials, equipment, transport, consumption of energy and time related cost factors that augment with delays and disruptions***. It is conspicuous that the conventional project management techniques are not suitable for complex projects anymore.***

In order to beat this problem in the platform of micro scale; a project must adhere to a set of guidelines that allows both resources and tasks to perform in a contemporary manner to achieve predetermined project goals (Nesensohn *et al.*, 2013). In that case, elimination of non-value-added activities is one major step. This has influenced to initiate this research as a solution to relieve the chronic problems in the

industry; introducing a new thinking evolving a significant change in the industry disciplines, professional mind set and beliefs.

1.3. AIM AND OBJECTIVES

The aim of this research is "to identify the effectiveness of applying lean construction principles and practices in order to enhance the construction flow in the contractors perspective'', which is achieved through the following objectives;

1. Determining the current awareness towards lean construction within the Sri Lankan construction industry.
2. Investigating the barriers impeding LC and effectiveness of practically applying lean techniques in to two particular construction organisations from Sri Lanka and UK as a comparative Case Study.
3. Developing a conceptual framework with the trace of barriers identified for the implementation of lean thinking.
4. Verifying the proposed conceptual framework towards enhancement the construction flow that leads project prospects.

1.4. RESEARCH METHODOLOGY

The research is soundly based on a multiple case study design which is compiled as a comparative study between two case studies in the platform of mixed research method (qualitative and quantitative); that enquires how effective the application of lean construction principles in to Sri Lankan context is compared to UK. The aim mainly focuses on regenerating the construction management process in Sri Lanka extracting examples from a developed country; United Kingdom which has got the world's fifth-largest economy by nominal GDP (Lincoln and Syed, 2011). A case study is an empirical inquiry that investigates a contemporary phenomenon within its actual context when a clear boundary between aforementioned phenomenon and actual context cannot be drawn in the default situation (Zucker, 2009). Thus, the contemporary phenomenon of lean thinking is extracted from both the case studies to compare the barriers and benefits unambiguously. An extensive literature review is conducted precursory to the research to identify the key barriers to successful implementation of LC. The two case studies ultimately evidently prove the accuracy of those literature review findings.

Precursory, the prevailing awareness of lean construction is investigated within the Sri Lankan construction industry via face-to-face interactive informal interviews and a questionnaire survey.

Since the study has exploited multi method approach to collect data, 'pragmatism paradigm' is the chosen philosophy in this study. Inductive theory is employed in this research where as a conceptual framework is derived as an origination of an applicable generic theory with many observations and explorations (Creswell, 2009). As per the research aim and objectives mixed approach is the best fit approach in collecting data placing the investigation under qualitative multiple-design (case study) while the prevailing awareness is captured by a questionnaire survey, which simulates the quantitative method. A conceptual (generic) framework is generated which is capable of applying to any sort of a construction project, not surpassed/ outstripped the scope and delimitation mentioned in the case study. Table 1 below illustrates how the aforementioned objectives are achieved with the use of different research methods.

Finally the research itself asserts a recommendation with few suggestions for continues improvement and for the further development in the applicability of Lean Construction techniques in to practice.

Table 1: Adopted Research Methods Against the Objectives

Research Objectives	Adopted Research Methods						
	Literature Review	Questionnaire Survey	Informal Discussions/ Interviews	Web Based Discussion Threads	Case Study	Secondary Data Analysis	Desk Study
Objective -1	√	√	√				
Objective -2	√		√	√	√	√	
Objective -3						√	√
Objective -4					√	√	√

2. LITERATURE REVIEW

2.1. RATIONALE - ORIGINS OF LEAN

The credit of Lean as a production philosophy authentically goes to the president of Toyota Production System - TPS (Ballard and Howell, 1998). This system (TPS) was initially introduced by Japan after World War II when Japan required producing small batches of cars in many varieties in-divergent to the Ford principle of mass production (many products in same features) (Cho and Ballard, 2011). The Ford principle of mass production was appeared to be inefficient as speculated by Toyota. In virtue of that, Toyota introduced a new theory for production process known as 'Lean Production'- LP (Conte and Sergio , 2002). The main objective of LP is to improve production efficiency and provide the customer with high quality products for the best value (Ballard, 2000). The principles extracted in Toyota production system is consisted of two main pillar concepts as Just-In-Time flow (JIT) and 'Autonomation'- Smart Automation (Anon, 2005).

Koskela (2002) has reported that the adaptation of lean concepts in to the construction industry presented as a paradigm shift to the traditional construction and project management techniques where conceptualized in three complementary ways of transformation, flow and creation of value. Shortened, TFV theory of production is a radical triploid that has led to initiate lean production through a discipline of transformation the prevailing construction process (Luis *et al.*, 2006). Lean thinking differs from every other conventional methods because of its nature that is consisting of clear set of objectives for the delivery process, aimed to maximize the performance with the use of key performance indicators kept as a benchmark and concurrent engineering techniques that collaborate design, production process and delivery at a collaborative platform and fourthly controlling the production process throughout the life cycle (Fayek and Hafez, 2013).

When it comes to waste reduction, it is important to look at the whole stream and have a clear understanding of what the customers sees as value where value added activities are the main focus in the value stream while non- value added activities are deprived from the process soon the identification (Small and Yasin, 2011). Thereupon targets have to be set to eliminate waste and strive for perfection. For continuous improvement, the journey to be carried out on to a specific direction followed by fixed targets and monitor the progress more often resulted by the change.

2.2. LEAN PRINCIPLES

Fundamentals for the elimination of waste

1. ***Identify Customer Value*** **-** Specify the value from the perspective of ultimate customer. It is essential to meet the required specifications and to deliver the value desired to the end customer. By clearly defining value for product or service, customer value becomes the common focus for parties involved in the project.

2. ***Map the Value Stream*** **-** Clearly identify the aspects that add value to the customer and the aspects that do not add value to the customer in both production flow and design flow. This is also known as value stream mapping, which also includes eliminating all the non-value added tasks and resources used within the flow.
3. ***Smoothening the Product Flow*** **-** Taking the remaining value adding steps in to flow without interruption by managing all co-related activities to achieve best sequence of work. This will simultaneously minimize the waste production as well as increase the value.
4. ***Use the Logic of 'Pull'*** **-** Compile the production line as per the customer demand and when the production is needed, making the production line much speeder.
5. ***Pursue Perfection*** **-** Pursue perfection by continuous improvement in all possible tasks of the process.

3. LEAN MANUFACTURING TO LEAN CONSTRUCTION

Lean construction was developed by the establishment of Lean project delivery system (LPDS). As per Ballard and Howell (1994), LPDS is consisting of four main domains; definition of the project, lean design, lean supply and lean assembly. Besides, some of the lean techniques are used in construction projects such as; flow variability, process variability, continuous improvement and transparency (Salem *et al.*, 2005). LPDS often incorporated with eliminating waste. Waste in construction process are identified as a non- value added aspect. Types of construction waste include Quality costs (12% of total project cost); Quality cost during operation (4% total project cost); Lack of constructability (6-10% of total project costs); Poor materials management (10-12% of labour costs); Excess consumption of materials on site (10% on avg.); Working time used for non-value adding activities on site (Approximately 2/3rd of total time); and Lack of safety (6% of total project costs) (Issa, 2013). Some of the main causes of Construction Waste can be overproduction, idle-time, transporting, processing, inventory, ineffective operator motions, generation of defective products, task initiation before having sufficient resources in-hand and communication inconsistencies.

Implementing lean production philosophy to construction practise presents similar objectives of delivering a competitive product in the minimum possible time period, with maximum value and quality and at a lesser/ reasonable cost (Gamal, 2013). In that case the application of lean thinking in to construction practise resembles with the lean principles originated form Toyota Production System. Traditional construction practices are always 'contract-centred' where stakeholders naturally act as per their own preference in order to optimize their own assigned set of tasks (Koskela, 1992).The conventional method is to shorten the project duration by accelerating the assigned activities of the program of plan by feeding labour, material and equipment in a much higher rate. The cost-related activities that are emerged from re-work, extended duration along the critical path can be minimized by the application of lean (Ballard and Howell, 1998). Lean construction does not exploit making changes to the schedule or the program of work plan; instead improve the delivery with the means of increasing the ultimate value. Lean planning often involves planning the work flow for a much ahead of time where traditional techniques concentrate more on the pre-determined milestone achieving via the sequence of critical path. Lean thinking is ideal for complex projects that are equipped with higher uncertainties as well as fast track projects.

Table 2 speculates the key aspects of lean construction summarized after an extent literature review.

Table 2: Key Aspects of Lean Construction - Literature Review

Key aspect	Summary	Authors
Just-In-Time (JIT)	Minimum number of inventories made according to the requests only, construction levelling and minimizing the amount of activities. Eliminating waste through continuous improvement	Salem, *et al.,* (2005) Koskela (1992)
Total Quality Management (TQM)	Concept of integrated management system, clear understanding of customers' expectations	Small *et al.* (2011) Summers (2005)
Concurrent Engineering (CE)	Involving right from the design phase, incorporating the constraints of sub-phases in to the inception phase and feeding the essence of change control upon the design process	Koskela (1992)
Last Planner System (LPS)	Minimize the project uncertainty by planning backwards of a target, increasing the commitment of team members that involves with project flow and variables.	Salem *et al.*, (2005)
Value Based Management (VBM)	Ultimate value for the customer is highly concerned while value for the team workers are also concerned as 'process value'	Bertelson (2004)

3.1. IDENTIFICATION OF GAP IN THE EXISTING LITERATURE - BARRIERS

Efforts for Lean Construction (LC) management in extant UK appear to be highly rewarding. After emphasizing the concept of Lean thinking by John Egan in his report of 'Rethinking Construction', UK construction industry arose to quest ways of adding more value to their deliverables via improving quality and efficiency. Although it is much consolidated in UK, various countries around the world are now in the quest of seeking more value with this thinking. However, numbers of structural and cultural barriers are to be seen that are militating against its successful implementation despite of the geographical area (Sarhan and Fox, 2013).

Despite these continuous efforts, studies show that the presence of lean culture in the large construction companies in UK is still less than what is professed by literature. More over the study recognizes a significant gap in the LC in other developing countries compared to UK, which evident the immense room to be improved in LC all around the world in general (Bhargav *et al.*, 2013).

Once in the era of late eighties the construction industry has been treated isolated from all the other industries and was claimed to be far different from manufacturing because of the belief that construction is different; with more complex concepts and take place under huge risk of uncertainties and constraints where every product output is unique (Salem *et al.*, 2006). On the other hand, Egan (1998) refuses this fact and claims that the construction industry includes many repeated processes which resembles manufacturing industry which enables to learn lessons from past models and can be used for future improvements. Re-engineering construction and learning from the past modes are the two main points (Egan, 1998). An extensive literature review comprehension was conducted to understand the possible barriers to the successful implementation of LC. Based on that, this study classifies these barriers into ten different categories, as shown below.

Table 3: Barriers to the Successful Implementation of LC

Barrier	How it Impedes the LC	Author/s
Fragmentation and subcontracting	It is essential to establish effective communication between all parties by partnering and integrated team-working. Poor communication will negatively impact on the coordination system as well as inefficiency in project delivery.	(Forbes *et al.*, 2002)
Procurement and contracts	Traditional Procurement methods often create adversarial relationships between parties involvedand can add waste to the process while bypassing the possible lean techniques.	(Mossman, 2009)
Culture and human attitudinal issues	lack of commitment, lack of team work, lack of self-criticism, poor communication, poor transparency, difficulty to adopt the new methodology, fear of risk taking, dependency, lack of incentives and motivation, and contractual disputes are few main aspects falls in to this.	(Common *et al.*, 2000)
Commercial pressures	Tendency of construction firms to apply traditional management concepts (dues to cost pressures) impedes continuous improvement and lessen productivity and quality initiatives.	(Common *et al.*, 2000)
Financial issues	A sufficient funding is required to successfully implement LC in to practice for required tools and equipment, remunerations, HR rewarding systems, training and development, etc.	(Bashir *et al.*, 2010, (Mossman, 2009)
Lack of top management commitment and support	New strategies need to be supported and motivated by top management. They should allowadequate time and resources to develop the strategy as well as manage the changes occur during the process.	(Bashir *et al.*, 2010)
Design/ construction dichotomy	Ignoring the importance of design & planning could lead loss of time, cost and quality. Design and initialization of design are treated separately in conventional methods which creates conflict and as well as waste.	(Common *et al.*, 2000)
Lack of adequate lean awareness/ understanding	Lean is more a conceptual thinking than a consumption of tools and equipment which needs to be very clearly understood. Collaboration, flexibility, commitment, discipline, and a broad thinking are few of them to be transformed.	(Common *et al.*, 2000)
Educational issues	Educational barriers produce greater threat to the sustainability of LC. Some of these barriers include:lack of technical skills, poor HR management, inadequate training, lack of awareness and understanding, lack of team spirit, poor illiteracy and computer illiteracy.	(Bashir *et al.*, 2010)
Lack of customer-focus	Measuring the project performance according to the ultimate client satisfaction is rare in many construction projects. Time-cost-quality focus measurement conventional; which needs to be changed.	(Forbes *et al.*, 2002)

Hence with the aforementioned barriers identified through literature review is evidently cross checked through the two case studies while investigating the benefits in order to generate a framework that can be used ambiguously to apply lean thinking in every construction project.

4. QUESTIONNAIRE

In order to achieve the first objective of 'determining the current awareness towards lean construction within the Sri Lankan construction industry', a questionnaire survey was conducted within an organisation; one of the largest construction companies in Sri Lanka. The questionnaire was exploited to investigate the awareness of lean construction among industry people with respect to few main factors

that impact the construction flow. Based on this questionnaire and the extent literature review, the problem of the research was identified.

The questionnaires were distributed among construction engineers/ planners/ designers/ quantity surveyors/ project managers within the same organisation. The selected organisation is one of the leading (C-1), established construction firms in Sri Lanka which deliver building construction, infrastructural and design-build solutions. Achieving the Sri Lanka's Corporate Accountability Index Platinum Rating, Second Rank for 2 recent years is one of the major achievements of this company. The company is endorsed with an array of international ventures that confirms the stability organisational management system. The reason behind selecting this company is their tendency to enhance the quality of work by setting up new strategies and policies updated in each year while the HR management is also remains a higher standard.

The sample size was 30 number of heads with a mix of aforementioned disciplines. The questionnaire forms were distributed by hand and the number of respondents received back was 24, which leads to an 80% of respond rate. The questionnaire used was a Likert-type scale from 1 (very low) to 5 (very high). The results showed that (figure-4) 58% of the respondents' awareness of lean techniques and principles were very low (almost no awareness) while 35% of the respondents were moderately knowledgeable about the same. The investigation resulted that more than half of the percentage was not aware of the Lean Concept but was interested on learning withal, having the capability to introduce lean thinking in to practice within their company. The inference of being less knowledgeable about the lean principles leads to way forward of this research to examine a case study that applies lean construction techniques in to the same organisation.

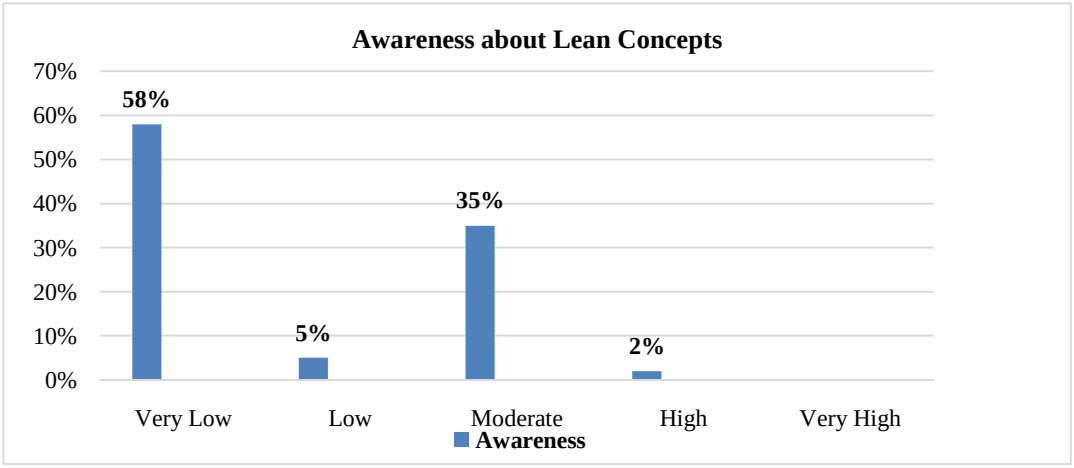


Figure 2: Awareness of Lean Principles

5. CASE STUDY

5.1. CASE STUDY INITIALIZATION

Multiple design longitudinal case-studies is the case study design exploited here. The unit of analysis is 'Construction performance' in which the performance is examined before and after applying lean construction techniques. The main lean construction technique considered here is the Last Planner system. LPS is practically applied in 2 different organisations from UK and Sri Lanka as a comparative study.

The reason for the selection of LPS as the 'application of analysis' is that application of LPS is one of the most effective ways to increase efficiency of construction performance by improving planning and control process (Aziz and Hafez, 2013). One of the best known Lean techniques is the Last Planner System which has proven to be a very useful tool for the management of construction process to repeatedly monitor the performance efficiency, to assist in developing foresight, smoothing workflow variations, and reducing/removing uncertainties in the entire construction process (Aziz and Hafez, 2013).

The findings are finally interpreted with descriptive explanations derived from comparing and contrasting strategy. Data was primarily collected from interactive discussions with professional who are actively engaged with the project. Project related documents; databases were used as secondary data for the analysis of the case study as qualitative data. An extensive literature review is speculated all over the research supporting each and every part of the argument brought in.

5.1.1. CASE STUDY - 1

Table 4: Project Profile (Travelodge)

Project Name	**128 Bedroom Travelodge Hotel, Hounslow, United Kingdom**
Status	Constructed and currently functioning
Employer	Travelodge Hotels Limited
Duration	65 weeks
Project cost	£ 5.7 million
Main Contractor	Barnes Construction

The project comprised the construction of a 128 bedroom Travelodge hotel including regenerating an area that contained a number of derelict dwellings. The project incorporated modern methods of construction and was procured under negotiated design and construct method. This hotel and leisure project sustained a PPC nearly 95% at the last month of the project. The relatively few subcontractors involved during the measurement period may have simplified the coordination problem beyond the norm (Sicat, 2012). However, the skill of well coordination between sub-contractors, client and the main contractor with an extensive involvement of subcontractors especially in planning and constraints analysis is a good point that can be followed by every company.

The two main objectives of LPS are to make better performance to direct workers through continuous learning and corrective action and to cause the work to flow smoothly across the deliverables in the best achievable sequence and rate (Anon, 2005). The last planner integrated components are: master plan, phase planning, look-ahead planning, weekly work planning, Percentage of Promises Completed on time or Percent of Planned Completed 'PPC' (A measure key of the Last Planner System success) (Aziz and Hafez, 2013). PPC only measures the effectiveness of the planning, not productivity. But the effectiveness of planning ultimately makes visible the greater productivity.

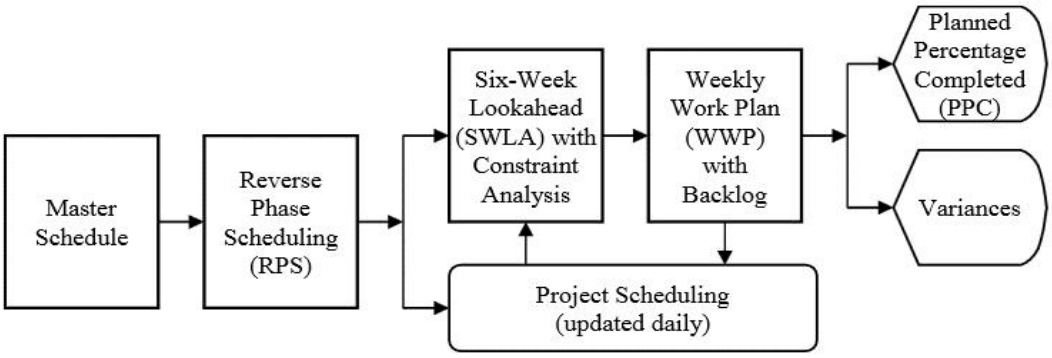


Figure 3: Sequence of LPS
Source: Zimmer (2005)

The figure below illustrates the results of implementation of the LPS on the above project, which clearly reflects the positive impact of the system on budget and productivity. Reported benefits attributed to LPS implementation were as follows: (1) cost reductions, (2) reliable predictions for planning, (3) smoothen the construction flow, (4) reductions in project duration, (5) improvement in productivity, and (6) greater collaboration of work among sub-contractors and client/ main contractor. Challenges faced by project

participants when applying LPS were also identified as follows: (1) lack of understanding due to poor training, (2) organisational inertia, (3) resistance to change, (4) poor leadership/ guidance, (5) contractual disputes, and (6) lack of experienced people. Last Planner System (LPS) has four main elements such as; (1) Programming Workshop: Collaboratively creating and agreeing production sequence (and shrinking the sequence when needed); (2) Make-Ready: Making tasks ready so that they can be done when we want to do them; (3) Production Planning: Collaboratively agreeing production tasks for the next day or week; and (4) Continual Improvement: Learning about and improving the project, planning and production processes.

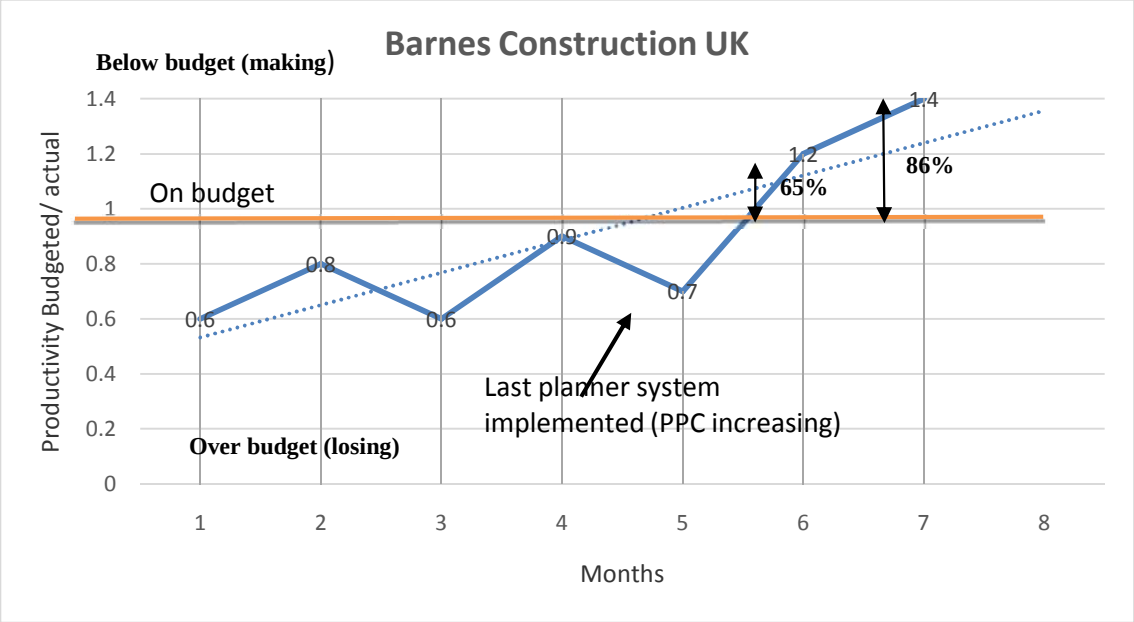


Figure 4: Productivity Improvement Using LPS-Barnes Construction

Look-ahead planning is the process undertaken to achieve possible constraints, free assignment, and cut down uncertainty. In the case study, look-ahead schedules were prepared for the upcoming three weeks in a bar chart format. WWP is produced based on three weeks look-ahead, the master schedule, and field conditions using notes and memos. Look-ahead schedules were updated on a weekly basis during a weekly project meeting. WWP should emphasize the learning process more by investigating the causes of delays on WWP instead of assigning blames and only focusing on PPC values (Ballard and Howell, 1998). On the other hand, PPC is also calculated every week during the project execution. The PPC is the measurement metric of the last planner system. It is calculated as the number of activities that are completed, as planned, divided by the total number of the planned activities. The upward slope between two PPC values indicates that production planning was reliable and vice versa. It is clear from this figure that there is a significant improvement for the values of PPC, with as increase in time, as the PPC values increase.

5.1.2. CASE STUDY - 2

Grand Hyatt Colombo (GHC), formerly known as Ceylinco Celestial/ Celestial Residencies/ Hyatt Regency Colombo is a 43-floor hotel/ apartment projectis Sri Lanka, which is also known as the tallest building in Sri Lanka up until now. The hotel will feature 475 guestrooms and 84 serviced apartments, as well as a lobby lounge, an all-day dining, multi-cuisine restaurant, three specialty restaurants, a bar, eight spa treatment rooms, a fitness centre, a swimming pool, and a Regency Club lounge. Additionally, the hotel will offer more than 17,000 sqft (1,579 sq m) of enclosed meeting space, including a 7,500 sqft (696 sq m) ballroom. The profile of the project is as follow;

Table 5: Project Profile (GHC)

Project Name	**Grand Hyatt, Colombo**
Status	Construction In-progress
Employer	Sri Lanka Insurance Corporation Ltd.
Developer	Sinolanka Hotels & SPA (Pvt) Ltd.
Consultants	Design Consortium (Pvt) Ltd., Archetype Group
MEP Contractor	Transgulf Electro mechanical
Interior Design Consultant	BilkeyLlinas Designs
Height	176 m (577 ft)- Excluding the pinnacle
Number of Floors	43 floors (Tallest building in Sri Lanka as at 2015)

5.2 CASE STUDY ANALYSIS

Grand Hyatt Colombo was expected to be opened and functioned in 2014. The project duration is now notably dragged with the approval of an extension of time. Furthermore, the project is under construction with numerous variations which apparently reports a significant cost over-run than the amount estimated at the tender stage. Hence it is conspicuous that the project is running with a noticeable cost and time over run. As per the face-to-face informal discussions/ interviews had with project managers and the engineers of the project the following points were emerged as some of the main factors that has been caused to result cost and time overrun.

Table 6: Causes of Cost and Time Overrun - GHC

Sort	**Causes for Time and Cost Overrun**
Labour	Higher rate of overtime performance Labour productivity
Material	Fluctuation of prices of materials Shortages of materials Changes in material specification and type Delay in delivery of materials Higher dependency on imported materials (delays in BOI approval)
Machinery/ Equipment	Equipment availability and failure Late delivery of equipment Insufficient number of equipment
Unforeseeable Conditions	Unpredictable weather conditions/ political influences Risk and uncertainty associated with the project
Cost Related Aspects	Financial difficulties of owner (fund approval by the government, SL) Delay payment to supplier/subcontractor Delay in progress payment by owner Cash flow and financial difficulties faced by contractors Poor financial control on site
Project Management	Lack of proper training and experience of PM Complexity of works Lack of appropriate software- use of conventional manual methods Ineffective planning and scheduling of project by contractor
Contractual Aspects	Severe Design changes/inadequate details/ incompleteness of drawings Discrepancies in contract documentation Conflict between project parties Draw-backs of suppliers Not using advanced engineering design software and tools

Howell and Koskela (2000), criticizes the conventional management techniques that are currently used and expostulate that conventional methods are yet insufficient to cope with project complexity and

uncertainties. Hence, the research itself suggests the following methods accompanied with lean construction approach to replace the existing method of practice.

Table 7: Traditional Methods that has been Used so far in GHC which can be Replaced with Lean Construction Methods

Function Used in GHC	Conventional Approach Currently In-Use in the Project	Lean Construction Approach
Process control	Corrective actions are taken only after the defective activities are identified in progress meetings	A reliable work flow is created much earlier where possible uncertainties are identified and on-site activities are applied in a virtual platform
Progress measurement	Each activity is treated separately to achieve the optimization	Maximizing value with a minimum waste, treating the whole project as a unit
Definition of value	Lowest cost is always considered as the best value	Customer requirements are carefully met at over the course of the project where best value is not always the lowest.
Task Management	Driven by push where products are almost made even before assessing the customer satisfaction. Over production is always there.	Driven by pull; mostly the outputs are offered only after the demand is received (building what is actually needed only with minimum waste)
Management hierarchy	Decisions are always made by one manager.	The participation of all the people involved in the project is valued in decision making (More transparency)
Back loading	Low flexible for variations and mitigation process is not addressed most of the times	Variations are expected and a provision is made at the early stage where the capacity of the project is made adjustable to absorb all possible variation.
Collaborative wok	Collaboration is very low where all the parties are worked separately with their assigned tasks.	Collaborative work among all the parties is in abundance.
Continuous Improvement	Continuous improvement is not considered and more focused on finishing off the assigned works only.	Continuous improvement is a major concern where future prospects are also aimed.

5.2.1. IMPLEMENTING LAST PLANNER SYSTEM (LPS) TO GHC

Last Planner system was introduced to GHC project to examine the effectiveness of Lean Construction techniques in to practise. LPS is associated with the pull approach that looks ahead of the project and schedules backwards. This assures the reliability and predictability of work flow as well as performance.

Initially the site supervisors were made aware of the LPS and were asked to assign work to the crew as it allows the conversations between the site management and the trade foreman at suitable level of detail preventing critical issues o happen on site. A six week look-ahead schedule was given to the site supervisor and they were asked to prepare a reverse phase scheduling looking at the programme six week ahead. As shown in the figure below, the site supervisors were instructed perform reverse-phase scheduling, Variance Analysis and Percentage Plan Completed Charts. A baseline was formed to measure the actual and planned as previous performance as percentages.

Initially, the last planner system was greeted with disbelief among the site workers as well as superintendents. The interviewees stated that the collaborative approach is in a doubt in which all the performers identify what exactly their duties and responsibilities are plus, what they expect from each other to achieve milestones, which is also called “pull- planning”. The last planner system addresses the scheduled activities in detail, far in advance of when the conditions on site can be known. This actually optimizes the flow rather than trying to optimizing each and every task separately. Examples from Toyota

practice is again to be applied hereto, as everybody in the line are responsible to stop the flow where ever a problem is encountered. The last planners are responsible to carry on the flow if only each and every activity is performed safely, efficiently and according to required quality standards. Defective inputs or mid-assignments are always bound to reject just as in Toyota production line.

When the integrated project team uses pull-planning to schedule the work flow related activities identified through value stream mapping strengthens the flow as everybody in the line learn to make clear requests to the other while making reliable promises as well. This ensures that installations are error free and can be constructed/ installed safely, efficiently and according to the particular standard by the assigned performer line. Therefore, the quality becomes the responsibility of designer, craft workers to managers, not just quality controllers and inspectors. In that case the documentation must be very clear and understandable. The output must meet the customer requirements and must fit with all the other components and assemblies as per visualized in the virtual design.

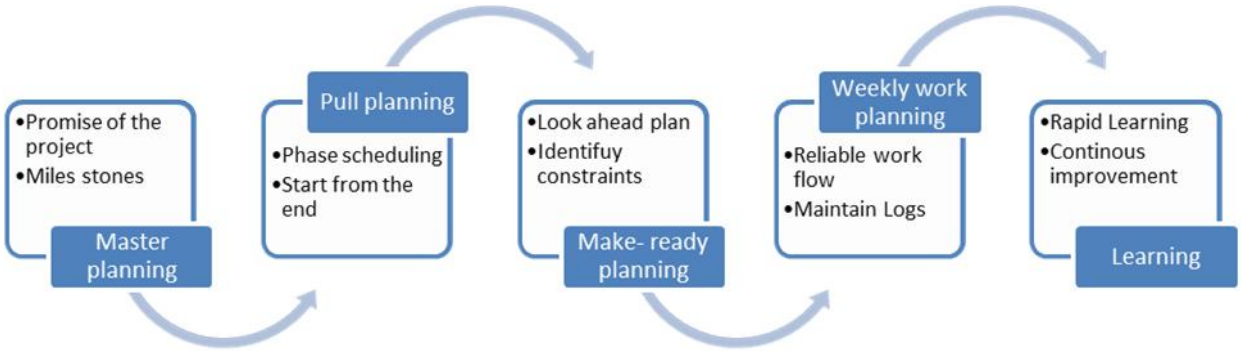


Figure 5: Last Planner System
Source: Zettel (2008)

After implementing last planner system, the performance of a particular trade was observed and the following were the competencies achieved; summarised as per the observation; Weekly accomplishment is measured as Percent Planned Complete (PPC) which is the number of completed assignments divided by the total number of assignments. The aim is to have tasks completed as planned. The project manager and site supervisors involved in controlling the process. Site supervisors seemed encouraging workers to be successful with their efforts.

Table 8: Lean Construction Tools Applied and Achievements

Scope	LC Tools Applied and Achievements	Achievement
Waste Reduction 42%	The concern to reduce the non-value added activities in the project	√
	The range of material waste in construction site	√
	The awareness of the employees about waste elimination	√
	The concern about unneeded movements when locating the inventory on site	√
	Material waste quantification	-
	Productivity loss quantification (labour/equipment)	√
	underutilized people on project considered as a waste	√
Transparency 85%	Visual management system at site	√
	Clarifying the whole method of construction to employees on site	√
	Communication channels with all the project stakeholders	√
Reduce Variability 67%	standardize the construction/design process	-
	communicate standard process to workers	√

Scope	LC Tools Applied and Achievements	Achievement
	reviewing the design drawings at early stages	√
Flow Variability 58%	visualization tools on site/project to improve work flow	√
	just-in-time method to decrease the volume of inventory on site	√
	collaboration with the suppliers to assure the delivery of material on time	√
	the work flexibility on site	√
	Schedule look-ahead to improve the work flow	√
	Management system to guarantee that the information flows smoothly	√
	The importance of the information flow, material and equipment on site	√
Continuous Improvement 66%	Quantification of the unused ordered material on site	-
	Pre-fabricated material on site	√
	Monitoring the production on site and record performance benchmarks	√
	Proactive actions or set quality plans to prevent defects at source	√
	The lesson-learned gained from your previous experience	√
	the employees contributing in the process enhancement	√
	Continuous education programmes or courses for the employees	√
	Consider the customer feedback to improve the process	√
Process Variability 63%	Start of the day meeting for all the employees in the project	√
Customer Focus 88%	The flexibility to meet the customer's changes & requirements	√
	Communication between the contractor and the customer	√

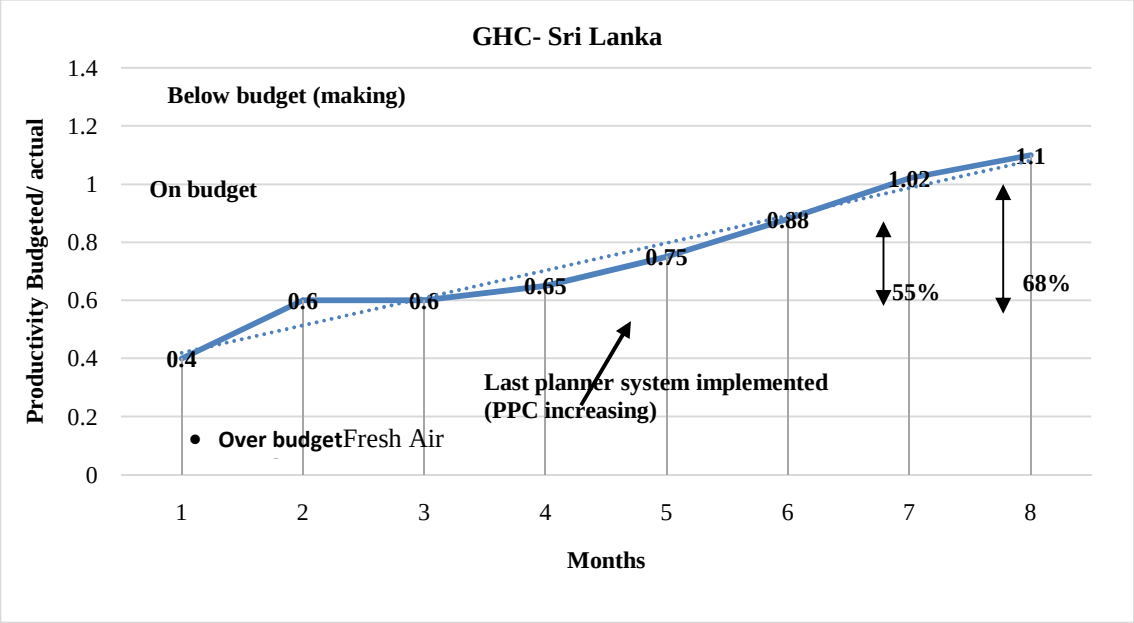


Figure 6: Productivity Improvement using LPS - GHC

5.3. FINDINGS OF THE CASE STUDY

It is found that the construction waste have been brought up to minimal with the increment of employee involvement. Leading time was minimized and a better way of utilizing the staff was identified. The quality of construction outputs were reported in an outstanding level more than it used to be. Returns were increased and the competitive position of the project was increased as benefits of lean application to the project. Use of LPS has actually helped making labour and resources maximally productive while allowing the project to accommodate variables and smoothens the work flow. Since traditional working methods encourage the establishments of time frames against set targets, LPS encourages the establishment of value added tasks that are necessary for the project completion. With the decentralized decision making process, allowed the flow to efficiently match the labour with materials and resources. Reworking was minimized in to a very lower level.

Results from the study indicate that there are several benefits associated with implementation of lean construction methods. The overall perspective of professionals within the chosen case study indicates improvement in corporate image of the company, enhancement in process flow and productivity, sustainable development and increased compliance with customer's expectations are identified as the benefits. The study also identifies a connection between lean application and sustainability that is achieved through waste reduction, perusal of best value to the customer as well as the workers involved and overall satisfaction.

However barriers/ draw backs were also identified as the implementation was bit complex because of lack of management commitment and the fear of practising new methods.

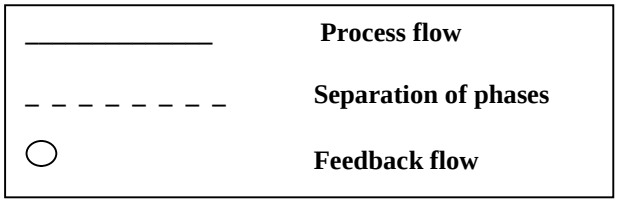
Evidence of the use of lean thinking has shown that there are many benefits to be made from applying lean principles to construction. These benefits claimed include: improved productivity, increased reliability, improved quality, more client satisfaction, increased predictability, shortened schedules, less waste, reduced cost, enhanced build-ability improvements to design, and improved safety.

Although project time has been reduced as a result of using lean construction techniques, not all factors are affected by these techniques. Price fluctuation, delay in monthly bill settlement and approval of payment to the main contractors design errors and adaptability to the environment, and poor quality of local materials were few attributes not affected by the application of LC. More research areas are open to study using a time-overrun quantification model; a PET analysis can be done to measure the effectiveness of LC application.

6. CONCEPTUAL FRAMEWORK

With all the findings a generic conceptual framework is formed to apply the same LC principles in a much familiar way. Lean techniques that associate waste elimination have the potential to reduce the overall duration of the activities and reduce the causes of delays and disruptions. The Framework is developed show how effective the implementation of LC practices can be acquired to in to the Sri Lankan construction industry. The framework is more suitable for projects that are full of uncertainties and that are in-need up speeding up.

Figure 7 illustrates the developed, proposed conceptual framework for Lean Construction implementation.



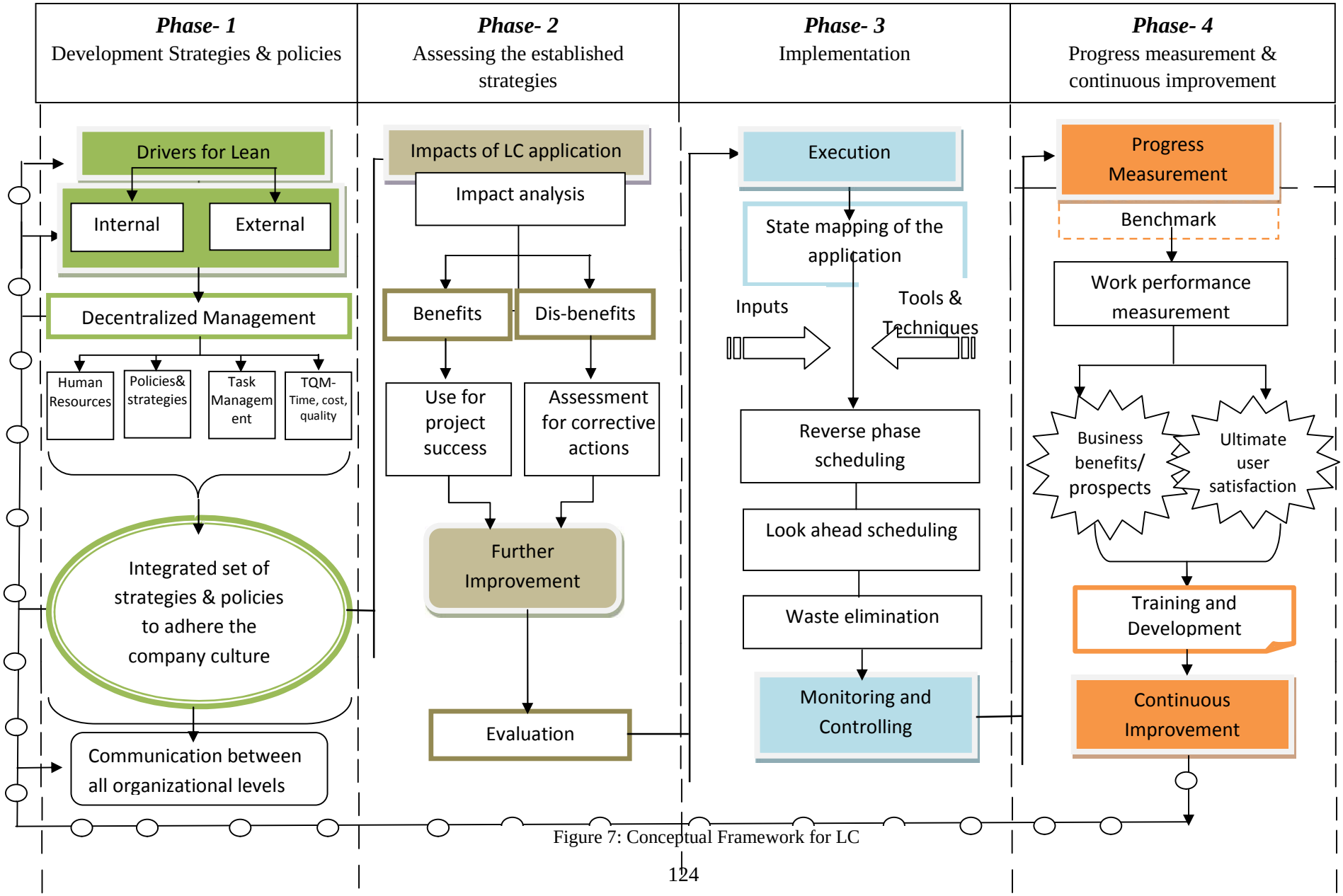


Figure 7: Conceptual Framework for LC

7. CONCLUSIONS AND RECOMMENDATIONS

Lean construction (LC) efforts evidently prove to be highly rewarding for the UK construction industry while it is still in the developing level (awareness raising status) in Sri Lanka. Although various countries around the world have gained numerous benefits by adopting the lean concepts, it does not seem to be rigidly applied in Sri Lankan construction industry as well as the awareness remains meagre. Numbers of structural and cultural barriers are browsed that cause hindering the construction performance towards achieving the lean approach. This study assessed number of barriers to the successful implementation of LC from an extensive literature review and three were identified and proven as significant, according to the two different case studies. Lack of adequate lean awareness and understanding; Lack of top management commitment; and Cultural & human attitudinal issues were the top three barriers identified in UK context, while financial issues, Lack of adequate lean awareness and understanding and Lack of top management commitment are the three main barriers identified in the Sri Lankan context. However despite the geographical location an organisation has the ability to gain profound benefits with the application of LC. Application of LPS is one significant step that has the potential to make a major fruitful change. Increment in project performance/ productivity is outstanding amongst them. Finally a generic framework was developed after identifying the pluses and minuses of LC practical application. Further research is required to verify the reliability and validity of this framework. Generation of Much detailed performance monitoring model is left for further research opportunities and actions.

The findings of this study could be used to help researchers, practitioners and companies to focus their attention and resources on the significant issues necessary to support the implementation of LC concepts.

8. REFERENCES

Anon, P., 2005. Lean Principles in Construction. *Construction Industry Institute (CII),* 101(1), 10-16.

Aziz, R.F. and Hafez, S.M., 2013. Applying Lean Thinking in Construction and Performance Improvement. *Alexandria Engineering Journal,* 15(4), 14-17.

Ballard, G., 2000. *Lean Project Delivery System.* s.l.: Lean Construction Institute.

Ballard, G. and Howell, G., 1998. *Implementing Lean Construction: Understanding and Action, Group for Lean Construction (ILGC) Proceedings.,* s.l.: s.n.

Ballard, H.G., 2000. *The Last Planner System of Production Control,* s.l.: Faculty of Engineering, The University of Birmingham.

Bashir, M.A., Suresh, S. and Gameson, R., 2010. *Barriers towards the Sustainable Implementation of Lean Construction in the United Kingdom,* s.l.: s.n.

Bertelsen, S., 2004. *Lean Construction: Where are We and How to Proceed,* s.l.: s.n.

Bhargav, D., Koskela, L., Kiviniemi, A. and Tzortzopoulos, P., 2013. *Lean Construction and BIM,* London: Elsvier.

Central Bank of Sri Lanka, 2015. *Research Studies,* s.l.: s.n.

Cho, S. and Ballard, G., 2011. Last Planner and Intergrated Project Delivery. *Lean and Integrated Project Delivery special issue,* 21(1), 69-72.

Common, G., Johansen, E. and Greenwood, D., 2000. *A Survey of the Take-up of Lean Concepts among UK Construction Companies.* Brighton, United Kingdom, s.n.

Conte, A. and Sergio, I., 2002. *Lean Construction- From Theory to Practice.* Gramado, Brazil: IGLC-10.

Creswell, J.W., 2009. *Research Design: Qualitative, Quantitative and Mixed Methods Approaches.* 3rd ed. s.l.:Thousand Oaks, CA: Sage Publications Inc..

Department of Senses and Statistics, Sri Lanka, 2015. *Gross Domestic Product, Sri Lankan Economy 2015,* s.l.: s.n.

Diekmann, M. and James, D., 1994. *Application of Lean Manufacturing Principles to Construction. Construction Industry,* s.l.: s.n.

Egan, J., 1998. *Rethinking Construction: The Report of the Construction Task Force to the Deputy Prime Minister John Prescott, on the scope for improving the quality and efficiency of UK construction,* HMSO, London: s.n.

Fayek , R. and Hafez, S., 2013. Applying Lean Thinking in Construction and Performance Improvement. *Alexandria Engineering Journal,* 52(4), 675–694.

Forbes, L.H., Ahmed, S.M. and Barcala, M., 2002. *Adapting Lean Construction Theory for Practical Application in Developing Countries.* Stellenbosch, South Africa., s.n.

Gamal, M., 2013. *Improving Project Performance Using Lean Construction in Egypt*, Cairo: s.n.

Glenn, B. and Greg, H., 1994. *Implementing Lean Construction: Stabilizing Work Flow, Reducing Inflow, 2nd Annual Conference on Lean Construction.*, s.l.: s.n.

Gregory, N., 2011. *What is the Last Planner System?,* Sheffield: s.n.

Howell, G.A., 1999. *What is Lean Construction.* California, USA, University of California, Berkeley, CA, USA.

Howell, G. and Koskela, L., 2002. *The Theory of Project Management: Explanation to Novel Methods,* Gramado, Brazil: s.n.

Howell and Koskela, 2000. *Reforming Project Management,* s.l.: s.n.

Issa, U., 2013. Implementation of Lean Construction Techniques for Minimizing the Risks Effect on Project Construction Time. *Alexandria Engineering Journal,* 52(3), 602-611.

Koskela, L., 1992. *Application of the New Production Philosophy to Construction Technology*, 21-25: CIFE.

Lincoln, F. and Syed, A., 2011. Lean Project Delivery and Integrated Practices- Taylor and Francis, USA. *Modern Construction Journal,* 8(21), 4-12.

Luis, A., Sven, D., Oscar , R. and Rodrigo, C., 2006. *Assessing the Impacts of Implementing Lean Construction.* Santiago, CHILE, s.n., 29-32.

Marhani, A., Jaapara, A., Bari, A. and Zawawi, M., 2013. Sustainability through Lean Construction Approach: A Literature Review. *Procedia - Social and Behavioral Sciences,* 101(3), 90– 97.

Marhani, A., Jaapar, A. and Bari, A., 2012. Lean Construction: Towards Enhancing Sustainable Construction in Malasia. *Social and Behavioral Sciences,* 68, 89-92.

Mossman, A., 2009. Why isn't The UK Construction Industry Going Lean With Gusto?. *Lean Construction Journal,* 5(1), 24-36.

Nesensohn, C., Demir, S. T. and Bryde, D. J., 2013. Developping the True North Route Map as a Navigational Compass in a Construction Project Management Organisation. *Lean Construction Journal,* 4-6.

Salem, O., Solomon, J., Genaidy, A. and Luegring, M., 2005. Site Implimentation and Assessment of Lean Construction Techniques. *Lean Constructio Journal,* 9(6), 3-7.

Salem, O., Solomon, J., Genaidy, A. and Minkarah, R., 2006. Lean Construction: From Theory to Implementation. *Journal of Management in Engineering,* 13(4), 8-11.

Sarhan, S. and Fox, A., 2013. Barriers to Implementing Lean Construction in the UK Construction Industry. *The Built & Human Environment Review,* 6(3), 8-11.

Sicat, S., 2012. *Lean Construction Management* [online]. Available from: http://www.fgould.com/north-america/articles/lean-approach/ [Accessed 27 April 2013].

Small, H. and Yasin, M., 2011. Assessing the Implementation and Effectiveness of Process Management Initiatives at Technologically Consistent Firms Business Process Management. *Construction Project Management Journal,* 20(6), 32-36.

Summers, D.C., 2005. *Quality Management,Creating and Sustaining Organisational Effectiveness.* Upper Saddle River, New Jersey: PEARSON Prentice Hall.

Zettel, G., 2008. *Transforming Turner Projects with Last Planer System,* s.l.: Turner Construction Company.

Zimmer, S., 2005. Application of Lean Manufacturing Principles to Construction. *Lean Construction Journal,* 5(4), 5-9.

Zucker, D. M., 2009. *How to do a Case Study Research,* Amherst: s.n