LITERATURE REVIEW: A CONCEPTUAL FRAMEWORK FOR PSYCHOLOGY IN LEAN CONSTRUCTION

Construction projects complete with cost and time overruns for various reasons. One of the major hindrances of flow process in construction activities is Non-value adding activities (NVAAs) such as rework, defects and waiting. Lean Construction (LC) is an innovative approach which is linked closely to the overall life of a construction project to ensure its success by eliminating NVAAs. The purpose of this paper is to establish a conceptual framework to reflect the link between lean construction implementation (LCI) and psychology. Literature indicates that the LCI at the operation level is limited. Moreover, LC is still new to many countries in the construction industry globally. Literature suggests many reasons for slow LCI such as lack of organizational elements, integration, training, administration and transparency. However, few addresses the human side, which is the psychology perspective.

A preliminary literature review was carried out to identify the psychological aspects of implementing lean principles in construction flow processes. Findings reveal that there is an evident link between the flow process and psychology in lean construction implementation. A conceptual framework is then developed to demonstrates the relationships between lean, construction and psychology. The activities that do not add any value to the final product are merely a waste and need to be minimized. Only limited efforts have so far been made to improve the flow process in the construction activities. Lean construction is one such attempt made to apply lean production principles to the construction industry to minimize NVAAs in its construction processes and maximize the value provided to clients. Hence it is vital to identify the key reasons for slow LCI to explore the human perspective. This paper recognizes the link between the LC and Psychology in the construction flow process. Furthermore, the conceptual framework is proposed to demonstrate the link between LC and psychology.

Keywords: conceptual framework, lean construction, preliminary literature review, psychology.

INTRODUCTION

Research Problem

The construction industry has been suffering from a range of challenges. Including low productivity, insufficient quality, time and cost overruns, poor safety, frequent disputes, lack of innovation, project asking so long and always exceeding the client's budget (Lathem (1994); Howel and Ballard (1997); Eagan (1998); Smith et al (1999); Kagioglou et al (2000); Salem et al (2006); Thomas et al (2010); Emuze and Smallwood (2011); Al-Aomar (2012); Vilashini et al (2012);Sarhan et al (2017), Rieden (2018; Tezel et al (2018). The main reasons are insufficiency and waste with NVAAs within the construction projects, not adding any value to the final product. Therefore, the NVVAs incur costs and hinder the performance of the construction projects and need to be minimized. Most construction managers fail to execute projects efficiently (Mahfuth at al, 2019).Moreover, the industry is vulnerable to multiple wastes, overruns, delays, errors, and inefficiencies (Al-Aomar (2012). Furthermore, Senaratne & Wijesiri (2008) have revealed that a considerable amount of waste lies in the flow processes of construction. The greatest obstacle to waste removal, in general, is a failure to recognize it. This is prevalent in the construction industry because it is not well understood by the construction personnel (Alwi et al., 2002). Waste is generally associated with waste of material in the construction process while NVAAs such as delays, transportation of material and others are not recognized as waste (Alarcon, 2006). The construction sector has a wide range of activities, including the provision of professional and technical inputs. Activities that do not add value result in waste which absorbs resources and does not add any value to the final product and therefore, these NVAAs need to be eliminated. By eliminating wasteful activities, processes can become 'lean' providing 'more with less' resources (Womack and Jones, 2010). According to Aziz and Hafez (2013), the traditional thinking of

most of the construction-related organizations is on conversion activities and flow activities and value considerations are simply ignored. LC is a new way to manage construction while minimizing the waste on flow activities. The goal of LC is to implement the project while maximizing value, minimizing waste, and pursuing perfection (Al-Aomar, 2012). However, lean construction implementation at the operation level is limited. Moreover, lean construction is still new to many in the construction industry globally. Many reasons for slow implementation have been suggested including, the lack of organizational elements, integration, training, administration and transparency. However, few addresses the human side, which is the psychology perspective (Moaveni, 2019). Hence, the proposed conceptual framework proves the psychological perspective of the LCI.

First, the common problems in construction flow processes were identified. One of the key concern is identified as the activities which do not add any value to the final output of the project and these non-value adding activities need to be minimized or eliminated for a smooth construction process flow. The literature also confirmed that the extent of existing NVAAs in the construction process flow, which creates unwanted cost and time overruns. The literature was then reviewed to identify the innovative management approaches to identify to improve the construction process flow, and Lean Construction was identified as the most appropriate ways of minimizing NVVAs in the construction process flow. It was revealed that there is a slow implementation in lean constructions in construction settings for many reasons. Moreover, the literature review was further carried out to identify the key drivers of lean construction implementation. These findings revealed that there is an evident link between psychology and lean construction implementation.

Research Method

A preliminary literature review was carried out to identify the psychological aspects of implementing lean principles in construction flow processes. The key focuses of the literature research were the prevailing issues in the construction sector, lean construction as a new approach, and the barriers in implementing LC. The journal articles published for recent years were the main source for the literature review. The keywords were identified as, NVAAS, LCI, and barriers for LCI. More than fifty number of journal articles were reviewed through google scholar, library resources, and lean construction institutes in different countries. In addition to this, the researcher's previous study on lean construction were also reviewed for key findings.

Literature for the last twenty years on lean construction implementation was critically evaluated to identify the link between lean construction implementation and human side of it. There were many pieces of literature from 1998 to 2005 on lean construction and its implementation. Also, this literature discusses the NVAAs as a waste which needs to be eliminated or minimized by implementing lean techniques. There were few kinds of literature from 2006 to 2012 and again, there is an explosion in the discussions of the Lean construction implementations from 2012 up to date. Guidelines, benefits and challenges were discussed throughout the whole period for the last twenty years.

As the next step of the literature review, the lean construction implementation was examined within developed and developing countries. Lucid chart software was used to frame the literature findings into a format. Moreover, the recently developed conceptual frameworks were examined through the literature review to refine the framework. Finally, a conceptual framework to demonstrate the link between LC and psychology was developed. This conceptual framework would further develop in future through a systematic Literature review followed by a primary data collection from different construction professionals in the Pacific Association of Quantity Surveying(PAQS) countries. It would be further detailed and refined via case studies from New Zealand Construction Industry.

The preliminary literature review shields three main sections. First, the research problem which is the existence of NVAAs in the construction process flow, and secondly, the most suitable approach to the research problem as LC implementation is discussed. The third section is to identify the link between LC implementation and psychology. Therefore, the next section of the paper presents the key findings of the preliminary literature review on NVAAs which hinder the construction process flow.

NON-VALUE ADDING ACTIVITIES (NVAAS)

NVAAs have been defined as the activities which do not add any value to the final product are merely a waste (Koskela, 1992). Most of these activities are intangible (Senaratne & Wijesiri, 2008) and invisible. Activities that do not add value are wasteful and should be eliminated. In the context of both construction and production, waste is primarily defined under seven categories (Ohno, 1988). These are defects (errors), delays, over processing, overproduction, excess inventory, unnecessary transport and conveyance of material and equipment, and unnecessary motions and movement of people According to Salem et al. (2006), there is a considerable waste in the construction projects which goes unnoticed. Previous studies (Senaratne & Wijesiri, 2008; Vilashini et al., 2011; Rahman et al. 2012) disclose that the workforce in the domestic construction industry is ignorant of these NVAAs that create waste and hinder construction performance. According to Koskela (2004), these wastes in the flow processes of construction such as 'non-conformance quality costs' consume a substantial amount of waste. Furthermore, he revealed the existence of these waste as 12% of the total project cost, poor material management results in 10-12% of the total labour cost, time used for NVAAs amounts to 2/3 of the total project time and lack of safety measures amounts to 6% of the total project cost.
A link exists between waste in a project and its cost. Waste is a major problem in the construction industry, and it amounts to 60% of the construction effort (Vilashini et all, 2011). A study focussing on the construction efficiency made by the National Institute of Standards and Technology in the United Kingdom indicates that 25-50% of waste relates to coordinating labour and managing, moving, and installing the material. Mossman (2009) has stated that 5-10% of the construction effort is for creating value, 30 -35% for supporting value creation and that 55-65% is wasted with much of the activity that supports value creation being logistics. Horman and Kenly (2005) have contended that as much as 49.6% of the construction operative time may be devoted to NVAAs. NVAAs have been identified as one of the problems negatively impacting on issues relating to variations. Waste that generates in the flow activities is recognized as a major disadvantage, which hinders performance and efficiency of constriction activities. Several authors, including Cornick (1991), Austin et al. (1994), and Koskela et al. (2001a) have identified these hindrances. They are poor communication, lack of adequate documentation, deficient or missing allocations, lack of co-operation between disciplines, unbalanced resource allocation and erratic decision making as the main causes for the poor performance of a building design process. According to Rahman (2012), every system contains waste. Vilashini et al. (2011) have disclosed that the analysis of the construction process indicates that construction activities can consist of 55% of Non-Value Adding Unnecessary Activities).

One-third of these activities result from factors under the control of management, such as rework and errors. Furthermore, Mahfuth at el (2019) identified two types of waste as operation waste and cultural waste. Operation wastes are rework, variation and negligence, unskilled labour, time restraint, poor communication, poor coordination between trades, and Inclement weather. The cultural wastes are lack of awareness, lack of incentives, lack of support from senior management, and lack of training. According to (Mahfuth at el 2019), waste can affect the success of construction projects in terms of cost, time, productivity, sustainability and environment. Construction waste management activities are inherent throughout the entire construction project life cycle from initial design to end/completion or demolition. Waste is classified into physical wastage on site but also on any form of inefficiency in productivity, work quality, handling and storage of materials, activity time and workers' movement. (Hwang et al., 2008), Elkhobar, Denanda and Trigunarsyah, 2011), (Katz and

Baum, 2011). Further, they have revealed that the most significant categories of NVAAs are 'defects' and 'waiting.' Furthermore, Thilakarathna and De Silva (2014) identified that NVAAs occur to the extent of 59% throughout construction projects.

Most of the construction projects are highly specialized, complex, with broad categories of stakeholders, with lead-time depressed durations for commencement, design and completion (Bryant and College,2002). Simialrly, Hosseini, Nikakhtar and Ghoddousi (2012) states that the construction industry is one with large specialized areas and disciplines. Construction project delivery system consists of three domains; the contract, the project organization and the project operating system (Thomsen et al., 2010). Furthermore, they stated that the project operating system had been largely neglected and this situation contributes significantly to inefficiency and waste. When focusing on waste, our attention is on what is not needed for the process of activities. All construction activities can be divided into two categories, conversion activities which produce tangible products and flow activities which bind such conversion activities during the delivery process of the output (Senaratne and Wijesiri, 2008). Waste that generates in flow activities is recognized as a major weakness which hinders performance and efficiency in the construction process flow. According to Vilasini, Neitzert and Rotimi (2014), there are several studies on process waste in construction, also stressed that individual waste in construction appears negligible, but if all this waste is added up, it can be substantial over time.

Construction projects have been identified to occur many injuries which lead to the suffering of people, unnecessary compensation costs, time overrun, productivity and efficiency reduction, material wastage and increased rate of employee turnover (Mahfuth at el 2019). No general trend concerning the outcome in terms of cost, quality, contract flexibility, avoidance of disputes, or construction time can be seen. (Johan Nystrom 2007). Furthermore, a lot of the criticism of the construction industry has also been focused on the inability to get the stakeholders of the project to engage cooperatively in the delivery of the client's objectives on time, cost and quality. Moreover, construction managers fail to execute projects efficiently. CMs have a significant role in creating and implementing strategies to deliver projects. Many researchers (Mosman, 2009; Horman and Kenley, 2005; Vilashini et al., 2011) have revealed that a major portion of time in construction is devoted to wasteful activities. These non-value adding activities are the major cause of schedule delays, cost overruns and other related problems in the construction process flow (Emuze and Smallwood 2011).

Hence, it can be concluded that there is a necessity for reducing these NVAAs, which destructively affect the productivity of construction and its value for money. Thus the value hindrance by the waste in the flow processes of construction is reasonably evident, and it indicates the necessity to implement a concept such as lean construction. The next section of this paper is dealt with LC and its implementation.

LEAN CONSTRUCTION (LC)

Overview of LC

LC is an innovative way to apply lean production principles to the construction industry to eliminate non-value adding activities in construction process flow (Koskela, 1992; Womack and Jones, 2003; Salem et al, 2006; Singleton and Hamzeh, 2011; Shang et al, 2012. The developing concept of lean construction is concerned with the application of lean thinking to the construction industry Rahman (2012) keeps an eye on the value-added element (conversion) as well as the non-value added elements (flow, delay, and errors) (Al-Aomar (2012). During the past ten years, there has been growing attention in investigating the extent to which the Japanese model of lean production can be applied in the construction industry among academics all over the world (Vilasini, Neitzert and Rotimi 2014).

LC assumes that construction is a kind of production process (Bertelson, 2004). The preliminary starting point for the approach is the claim that project teams are responsible for helping clients to decide what they want, not just doing what the clients tell them. Rahman (2012) has explored the key steps in the LC process. These are identifying client's budget, determining design criteria, target values and constraints. Lean construction is the continuous process of eliminating waste, focusing on the entire value stream, and pursuing perfection in the execution of a construction project. It also focuses on the way one activity can affect the next (Pinch, 2005). Work is structured throughout the process to maximize value and to reduce waste at the project delivery level. According to Rahman (2012), three features distinguish lean construction practice from conventional construction management. Firstly, LC focuses on reducing waste that may exist in any form in the construction processes such as inspection, transportation, waiting, and motion. LC also aims at reducing variability and irregularity so that material and information can flow in the system without interruptions. Last but not least, construction material is expected to be at the site only when it is needed. Mitropoulos and Tatum (2000) cited by Vilasini, Neitzert and Rotimi (2014) recommend a three-divided approach that integrates contractual, organizational and operational aspects to deliver projects successfully. Therefore, it is significant to consider the construction project as operational aspects of the project delivery system with a lean perspective.

Ballard (2008) divides the lean project delivery system into four interconnected phases, i.e., project definition, lean design, lean supply, and lean assembly. According to Sacks et al. (2010), addressing sustainable issues such as economic, social, and environmental values as the requirement of an owner, 'Lean' may perform from project definition to its construction phase. Moreover, a lean delivery emphasizes a cost-effective and on-time handover with no delays or rejects or quality issues (Al-Aomar, 2012). According to Salvatierra-Garrido J. and Pasquire C. (2011), LC experience commonly connects construction practices with the Transformation-Flow-Value model of Koskela, where value is mainly delivered during the production process at the site. Consequently, most of the efforts have been made to satisfy the client's (as the paying customer) requirements. Bertelsen (2004) have argued that the clients represent interests from three main groups; owner, user and the society who value different things at different times through the life cycle of construction projects. The different phases of the lean project delivery system are further discussed in the next section. The reliable release of work between specialists in design, supply and assembly assures value is delivered to the customer and waste is reduced. (Ballard, 2005 and 2008). The lean project delivery system emerged in 2000 from theoretical and practical investigations and is in the process of undergoing development in many parts of the world through experimentation. In recent years, studies have focused on the definition and design phase of projects, applying concepts and methods drawn from the Toyota Products (Barrald 2008). Lean construction implementation is discussed in the next section.

LC Implementation

The lean project management is focused on implementing the guidelines of the lean project delivery system developed by LCI (Ballard 2008). The lean project delivery system includes Lean project definition, lean design, lean supply and lean assembly. According to Ballard (2006 and 2008), the lean design phase transforms the conceptual design of the project into a lean product and processes the design to be consistent with project scope and design criteria. Furthermore, he states that the lean supply module consists of the detailed engineering of the product design, the fabrication or purchasing of components and material, and the logistics of deliveries and inventories. Lean assembly ranges from the delivery of tools, material, and components to commissioning and project delivery to the client (Al-Aomar (2012). Lean construction is a production management-based approach to project

delivery – a new way to design and build capital facilities. Lean production management has caused a revolution in manufacturing, design, supply and assembly. Lean changes the way the construction work is done through techniques and applies them to a new project delivery process (Vilashini, Neitzert & Rotimi (2014).

Project Definition: Defining value and waste is critical, and value management in lean production is an attempt to maximize value and eliminate waste (Bae and Kim, 2007). Ballard (2011) has revealed that cost, quality, time, location and other constraints are conditions that must be met to deliver value to customers. Target value design is a management practice that seeks to make customer constraints drivers of design for the sake of value delivery. According to Zimina et al. (2012), target costing stands for a range of techniques and methods applied as a part of traditional cost management, such as contract and cost management and target cost contract. It includes several phases, i,e client brief, procurement advice and budget, cost planning and control of the design stage.

Lean Design: The building design process involves thousands of decisions, sometimes taken over years, with numerous interdependencies, under a highly uncertain environment (Formoso and Tzortzopoulos, 1999). According to Paul (2005), lean design management is a new paradigm for managing design and construction. Moreover, it is a very difficult process to manage and usually lacks effective planning and control to minimize the effects of complexity and uncertainty. Therefore, Huovila and Koskale (1998) have proposed a conceptual framework for managing the design process in which three different views of this process. First, design as a conversion of inputs into outputs. Secondly, design as a flow of material and information. Finally, design as a value generating a process for the clients. Hence, recent researchers (Bae and Kim, 2007; Formoso et al., 1998) have discussed the application of some lean principles to design management.

Lean Supply: Pasquire and Connolly (2002) have revealed that lean production has made significant improvements in the manufacturing sector and that there is a simple argument that increasing the amount of factory-based manufacturing of buildings, their components, sections and elements would form one logical method for incorporating lean production into construction project delivery. Lean techniques such as Just in Time (JIT), Off-Site Manufacturing (OSM) reduce damages and material. Moreover, these methods may reduce the various sources of extra inventory. Further, Pasquire and Connolly (2002) have concluded that lean manufacturing has a direct application in construction through the pre-assembly of building components and that considerable benefits are available as a result of off-site manufacturing.

Lean assembly: Lean assembly is the phase beginning with the first delivery of resources to the site and ending with project turnover (Salem et al., 2006). Moreover, it is particularly important to general contractors during the construction implementation stage. Further, Salem et al. (2006) have expressed that there are approaches to lean assembly, i.e., flow variability, process variability, transparency and continuous improvement. However, the LC is implemented in the construction process and not always refer to the above four lean stages in the recent literature. The example of the commonly used lean techniques in the construction process flow is presented in below.

Lean Techniques: Several lean techniques have been developed for the manufacturing industry, and the implementation of these techniques in the construction process flow has been identified in the literature for the last two decades. The widely used lean techniques to provide more value with fewer resources are summarized in Table 1.

Table 1: The widely used lean techniques in Construction Flow Process

Ref	Lean Techniques	Sources
1	Last Planer System	Alarcon, L.F, Diethelm, S., Rojo, O. and Caldero, R., (2005, Al-Aomar R. (2012), Andersen B., Belay A M, and Seim E. A. (2012), Ballard, G., and Kim, Y.W. (2005) Ballard G. (2011), Salvatierra-Garrido J. and Pasquire C. (2011) Bae, J.W., and Kim, Y.W. (2007) Ballard G, (2008) Bertelsen, S. (2004) Cho, S, and Ballard, G., 2011 Christine L Pasquire, C. L., and Connolly, G.E. (2002) Ekanayake S. and Senaratne S. (2010) Genaidy A., Luehring M., Paez., O and Solomon, J.(2004) Hamzeh, F, Ballard G, Tommelein I D (2012), Howel, G. And Ballard G.,(1998) Jayasena H.S and wedikkara C. (2013) Koskela, L. (2004) Kalsaas B T (2012) Lean Examples in Construction, Report by the Construction Productivity Network, (2003) Luo, Y., Rilley D. R. and Horman M J. (2005) Mossman, A. (2009), Peng, W. And Pheng, S. (2010) Rahaman H A, Wang C, Lim I Y W (2012) Salem, O. and Zimmer E (2005) Salem O. Genaidy A., Luehring M., Paez., O and Solomon, J. (2004), Salem.O., Solomon.J, Genaidy, A. And. Luehring, M. (2005) Senaratne S. and Wijesiri, D., (2008) Report by the Construction Productivity Network, (2003) Tam V. W Y., Tam C.M., and William C.Y. N (2007) Thilakarathna N. and De Silva L. (2018) Tzortzopoulos, P. and Formoso, T. (1999) Vilashini, N, Neitzert, T R, and Rotimi, O. J (2011) Vilashini N. and Neitzert T R (2012) Zimina,D., Ballard, G., Pasquire, C.,2012 Belay A M, and Seim E A (2012),
2	Just in Time	
3	3D Modelling	
4	Visualization	
5	Value Stream Mapping	
6	Reverse Phase Scheduling	
7	Huddle Meeting	
8	Prefabrication	
9	Off-site Manufacturing	
10	Kaizen	
11	Five S	
12	Fail Safe Quality	
13	Target Value Design	
14	First Run Studies	
15	Relational Contracting	
16	Target Costing	
17	Set-Based Design	
18	Kanban Material Card	
19	BIM	
20	Total Quality Management	
21	Work Standardization	
22	Work Structuring	
23	Flow Charts	
24	Lean Production Philosophy	
25	Value Chain	
26	Increased Visualization	

However, several authors (Marhani, 2012; Ayarkkwa et al, 2012; Al-Nafil, 2013; Thilakarathna and De Silva, 2014; Sisbon and Eishennawy (2015); Harrison and Thurnell, 2015; Olnan and Abdulrahim, 2015; Habchi et al, 2016; Bajjou and Chafi, 2018) have explored that Lean construction implementation in slow. Moreover, LCI is still its infancy in most of the developed and developing countries such as Malaysia, UK, Libya, Sri Lanka, Moroccan, KSA and New Zealand for many reasons. Hence, it is vital to assess the reasons for the slow implementation of LC, and the next section presents the critical barriers for LCI and their relation to the psychology which is the mind and behaviour of human.

PSYCHOLOGY IN LEAN CONSTRUCTION

The preliminary literature review presented above discussed the research problem as NVAAs and the suitable approach to the research problem is LCI. This section presents the literature findings of the psychology in LCI. Furthermore, the barriers for LCI are assessed and the evidence is constructed through the barriers to establish the link between psychology and the LCI.

Psychology

Psychology is the scientific study of behaviour and the mind ((Passer & Smith, 2015). Social psychology and personality psychology are the subfields of psychology's diversity. Personality psychology focuses on human personality with core personality traits and the way different traits relate to one another and influence behaviour. Furthermore, Passer & Smith (2015) stated that social psychology examines people's thoughts, feelings and behaviour about the social world. How people influence one another, behave in groups and form impressions and attitude. Cognitive psychology is the subfield of mental process, especially from a model that views the mind as an information processor such as consciousness, attention, memory, decision making and problem-solving. According to Howell and Ballard (1998) in the early stage of LC lean production is a new way to coordinate action that rests on a new mental model. Moreover, Nesensohn *et al* (2014) identified eleven key attributes lean construction, and four of them are directly related to the psychological perspective. They are lean leadership; actively encourage and drive individuals, way of thinking: a holistic approach of thinking, change; a context towards LC is intrinsic, and work environment; working conditions to encourage individual and teams. People differ meaningfully in the ways they customarily think, feel and act.

Psychology in Construction

Chinyio and Taiwo (2016) suggest that construction projects require teamwork and proper integration for successful project execution and completion. Previous studies have implicated psychosocial factors as significant determinants of effective team behaviour (Brewer & Gajendram, 2011), progressive decision making, firm integrations, as well as strategic planning and innovativeness within the construction industry. However, the current built environment pedagogy does not provide a platform module in which the psychological perspective of all such factors is taught or examined. This psychological perspective cannot be overlooked within the reality of construction and manufacturing environment. We aim to design a multidisciplinary educational curriculum, tagged psychology in construction (Psycon) which will explore the various areas of human factor within the built environment as affected by psychosocial influences to create greater awareness of such factors to students as this will benefit their professional interactions with people. Furthermore, the current management practices show the recognition of the importance of the workforce is essential (Jong, Sim and Lew (2019). Moreover, it is proven that the workforce is essential to the construction industry.

Barriers in LCI

Some studies carried out by many types of research in various countries have identified the key barriers for LCI in the construction industry. Table 2 summarizes those barriers for LCI based on the critical literature review conducted for this study. Literature from 1999 to date informs us there are barriers to LCI in different perspectives such as technical, financial and human. Sarhan et al. (2018) deduced that barriers to LCI are similar to both developed and developing countries. The principal barriers are traditional practices, standardization, technological, financial and performance and knowledge related. Table 2 indicates that most of the barriers are related to the mind and behaviour of people. Moreover, Jelodar *et al.* (2018) concluded that there is a lack of innovation drivers within the construction projects. Furthermore, Bajjou and Chafi (2018) have also stated that there are two categories, people, related barriers (55.1%) and organizational barriers (44.6%). Hence it is evident that psychology is a key concern in LCI, and there is a link between psychology and LCI.

Table 2: The link between LCI and Psychology

Literature Reference	**Barriers in Lean Construction Implementation**	**Evidence to Psychology**
Tzortzopoulos and Formoso (1999)	there is a lack of interest among construction parties to sit for a weekly review meeting to solve the problems causing project plan failures	***interest***
Salem *et al.* (2005)	Changing mindsets and behaviour with lean thinking become a challenge and to eliminate this barrier; the contractor has to offer training and recognition.	***mindsets and behaviour***
Alarcon *et al.* (2006)	***Time***: the main difficulty being lack of time for implementing new practices in the projects, ***Training***: Lack of Training, ***Organization:*** Challenges to create organizational elements, ***Self-Criticism***: Lack of self-criticism to learn from errors and responding to deficiencies, ***Low understanding*** of the concepts, low use of different elements, inadequate administration, weak communication and transparency and ***lack of integration*** of the construction chain	***self-criticism: understanding integration***
Vilasini, Neitzert and Rotimi (2012)	Team members are to be interested in making changes, The unfamiliarity with lean concepts, Misunderstanding of Lean concepts, Challenges to create organizational elements, Lack of self-criticism to learn errors, responding to some deficiencies, Inadequate administration, Weak communication and transparency, Lack of integration of the construction chain, Negative attitude towards implementing new practices	***attitudes, interests, self-criticism***
Vilasini, Neitzert and Rotimi (2014)	To sustain a process improvement; team members to be interested in making changes, willing to extend their joint efforts, promote a culture of teamwork and problem-solving	***culture of teamwork***
Harrison and Thurnell (2015)	Cultural resistance to change to 5D BIM from traditional quantity surveying techniques within integrated project delivery	***resistance to change***
Ruan *et al.* (2016)	"People" as the main barrier, "they do not want to change from what they are," "cultural issues" create complications, "yet another burden on the workforce," common company philosophy, "thinking of senior management."	***people as the main barrier***
Khaba and Bhar (2017)	Lack of awareness and understanding of lean construction. A coherent philosophy is yet to be developed for lean construction. Resistance to change with a tendency to apply traditional management concepts. Lack of understanding customer needs, Cultural difference: organizational culture and professional motivation	***awareness understanding resistance culture motivation***
Guerriero *et al.* (2017)	A lack of integrated management tools in "lean management" in construction processes, data acquisitions relies on people treatment, and exclusively paper-based, data manipulation, practitioners involvement	***rely on people involvement***
Sarhan et al. (2018) ,	Organizational culture, Influence of traditional management practices, Lack of committed leadership of top management, Lack of clear job specification from the client, Lack of client and supplier involvement, End-user preference, Use of non-standard components, Slow decision making processes due to complex organizational hierarchy, Uncertainty in supply chain, Lack of support from government for technological advancements	***culture, influence commitment preference***
Bajjou and Chafi (2019)	Lack of knowledge about LC practices, Unskilled human resources, Resistance to change, Time and commercial pressure, Lack of commitment from top management, Culture and human attitudinal issues, Fragmentation and subcontracting, Insufficient financial resources, lack of government support, Fragmentation and subcontracting	***resistance to change pressure attitudes***

Bajjou and Chafi (2019) Lack of knowledge about LC practices, Unskilled human resources, Resistance to change, Time and commercial pressure, Lack of commitment from top management, Culture and human attitudinal issues, Fragmentation and subcontracting, Insufficient financial resources, Lack of government support, Fragmentation and subcontracting resistance to change pressure attitudes

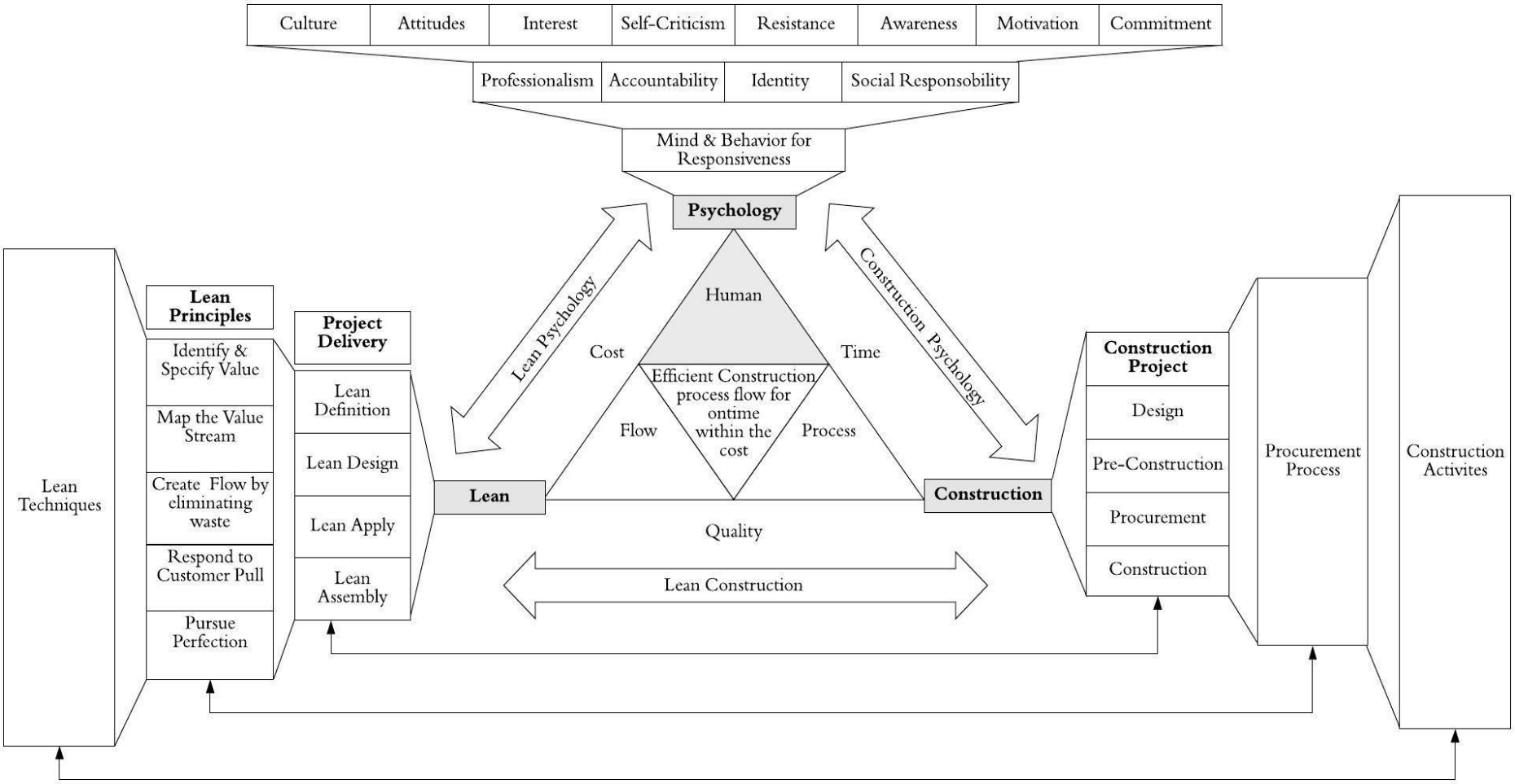
CONCEPTUAL FRAMEWORK

Literature informs us construction projects complete with cost and time overruns. One of the major reason is NVAAs, which incur costs and not do not add any value to the final construction project. Therefore, NVAAs need to be minimized for an efficient construction process flow to achieve the project deliverables of time, cost and quality. The LC has identified as one of the innovative approaches for managing projects by implementing different lean techniques developed and implemented in the manufacturing industry. There are many examples of the implementation of LC in construction projects from different countries over the last two decades. However, the background literature confirms that LCI is slow for many reasons. Hence the barriers for LCI were evaluated and tabulated in table 2 for further analysis. Moreover, these barriers were critically examined and identified that most of the barriers have a clear link to the mind and behaviour of people engaged in the construction process flow. All these literature findings were mapped to a conceptual framework as the last step of this paper.

A conceptual framework is a system of concepts, assumptions, expectations, beliefs and theories that support and indicates the research (Miles and Huberman, 1994; Robson, 2011). The conceptual framework developed through this literature review is presented in Figure 1. It has three main domains; lean, construction, and psychology. Lean is on the flow, construction is on the process, and psychology is on human. The centre of this framework is the output of the construction industry, which is a project with the efficient process flow to assure on time and within the cost. The iron triangle of construction project represents the cost, time and quality as project deliverables. Within this context, lean construction has been discussed in the literature for more than twenty years, and in the recent past, construction psychology emerged as discussed in this paper. Lean psychology is a novelty concept to construction management sector, and it is about lean and psychology.

This paper discussed that there is a clear link between psychology and the lean construction and the psychology in construction in the lean culture is the key driver for efficient construction process flow for on time and within the cost of a specific project. Furthermore, the framework emblems the psychological perspectives in Lean construction with culture, attitudes, interests, self-criticism, awareness, motivation and commitments. Moreover, this study will deeply look into professionalism, accountability, identity, and social responsibility as the next step.

Figure 1: A conceptual framework for improving construction process flow



CONCLUSION AND THE WAY FORWARD

The construction industry is suffering from low productivity, insufficient quality, time and cost overruns, poor safety, frequent disputes, lack of innovation, project asking so long and always exceeding the client's budget. Moreover, the construction sector has a wide range of activities that result in waste, which incurs costs and does not add any value to the final product. The traditional thinking of most of the construction-related organizations is on conversion activities, and flow activities and value considerations are ignored. Lean construction keeps an eye on the value-added element of the construction process (conversion) as well as the non-value added elements (flow, delay, and errors). The literature indicates that 'lean' minimizes waste and that lean techniques can be applied to minimize NVAAs in the construction projects. Lean is an innovative construction management approach which is linked closely to the overall life of a project ensuring its success. However, the background of this study indicates that Lean construction implementation in slow and is still its infancy in most of the developed and developing countries. Literature confirms that there are barriers to LCI in different perspectives and mind and behaviour of people who work in the construction industry is a key barrier for LCI. Moreover, when the barriers in LCI are further evaluated, it is evident that there is a link between Psychology and LCI. Finally, this paper suggested a conceptual framework to replicate the link between lean construction implementation and psychology.

The ultimate aim of this study is to develop a framework for improving construction process flow by implementing lean construction practices which emblems a psychological approach to embrace the lean culture for long term sustainability. The objectives of the wider research project are to; identify the hindrance of the construction process flow, assess the LCI, map the reasons for slow LCI with psychological aspects and to develop a framework for improving the efficiency in construction process flow with lean psychology. The research methodology will be a mixed method approach. A preliminary literature review to identify the link between LC and psychology was already done. The unit of analysis is "construction project," which completed recently. This research will continue with a survey and several cases studies and ending with experts' opinions to refine a framework for improving the process flow of construction activities with lean psychology.

REFERENCES

Alacon, L., Diethelm, S., Rojo, O. and Calderon, R. (2006). Assessing the impact of implementing lean construction. *14th Annual Conference of the International Group for Lean*, pp.26-33.

Al-Aomar, R. (2012). Analysis of lean construction practices at Abu Dhabi construction industry. *Lean Construction Journal*, pp.105-121.

Alwi, S., Hampson, K. and Mohamed, S. (2002). Non-value- adding activities; A Comparative Study of Indonesian and Australian Construction Projects.

Andersen, B., Belay, A. and Seim, E. (2012). Lean construction practices and its effects: A case study at St Olav's Integrated hospital, Norway. *Lean construction journal*, pp.122-149.

Austin, S., Baldwin, A. and Newton, A. (1994). Manipulating the flow of design information to improve the programming of building design. *Construction Management and Economics*, 12(5), pp.445-455.

Aziz, R. and Hafez, S. (2013). Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal*, 52(4), pp.679-695.

Bae, J. and Kim, Y. (2008). Sustainable Value on Construction Projects and Lean Construction. *Journal of Green Building*, 3(1), pp.156-167.

Bajjou, M. and Chafi, A. (2018). Lean construction implementation in the Moroccan construction industry. *Journal of Engineering, Design and Technology*, 4(16), pp.533-556.

Ballard, G. (2008). The Lean Project Delivery System: An Update. *Lean Construction Journal*, pp.1-19.

Ballard, G. (2011). Target Value Design: Current Benchmark. *Lean construction Journal*, pp.79-84.

Ballard, G. and Kim, Y. (2005). Implementing Lean on Construction Projects, Construction Industry Research Project.

Ballard, G. and Kim, Y. (2006). Implementing Lean on Construction Projects, Construction Industry Research Project.

Bertelsen, S. (2004). Bridging the gaps- Towards a comprehensive understanding of Lean Construction, *10th Annual conference in the IGLC.*

Bob, E. (2008). Practical Lean Leadership; A strategic leadership guide for executives, ISBN.

Chinyio, E. and Taiwo, A. (2016), *Psychology in Construction*, Conference proceedings, International Technology, Education and Development.

Cho, S. and Ballard, G. (2010). Last Planner and Integrated Project Delivery. *Lean Construction Journal*, pp.67-78.

Egan, J. (1998). Rethinking Construction; The Report of the Construction Task Force.

Ekanayake, S. and Senaratne, S. (2010). Sustainable benefits in Application of Lean in Prefabrication Production Process, *In the proceedings of International Research Conference on Sustainability in Built Environment,18th and 19th June 20110 at Galle Face Hotel, Colombo, Sri Lanka.* pp.40-49.

Emuze, F. and Smallwood, J. (2011). Non-Value Adding Activities in South African Construction: A Research Agenda. *Journal of Construction Engineering and Project Management*, 1(3), pp.38-44.

Formoso, C. and Tzortzopoulos, P. (1999). Developing a protocol for managing the design process in the Building Industry, *Proceedings IGLC'98.*

Guerriero, A., Kubicki, S., Berroir, F. and Lemaire, C. (2017). BIM-enhanced Collaborative Smart Technologies for LEAN Construction Processes. *Journal of IEEE*.

Halpin, D. (1990). International Competition in Construction Technology. *Journal of Professional Issues in Engineering*, 116(4), pp.351-359.

Hamzeh, F., Ballard, G. and Tommelein, I. (2012). Rethinking Look Ahead Planning to Optimize Construction Workflow. *Lean Construction Journal*, pp.15-34.

Han, S., Lee, S., Fard, M. and Pena-Mora, F. (2007). Modelling and representation of non-value adding activities due to errors and changes in design and construction projects, *Proceedings of the 39th Conference on Winter simulation, Piscataway, NJ, USA.*

Harrison, C. and Thurnell, D. (2015). BIM implementation in a New Zealand consulting Quantity Surveying practice. *International Journal of Construction Supply Chain Management*, 1(5), pp.1-15.

Horman, M. and Kenley, R. (2005). Quantifying Levels of Wasted Time in Construction with Meta-Analysis. *Journal of Construction Engineering and Management*, 131(1), pp.52-61.

Howell, G. and Ballard, G. (1998). Implementation lean construction – Understanding and Action, *Proceedings IGLC' 98, Guaruja, Brazil*.

Howell, G. and Ballard, G. (1997). What is lean construction?

Hozak, K. and Olsen, E. (2015). Lean psychology and the theories of "Thinking, Fast and Slow". *International Journal of Lean Six Sigma*, 3(6), 206-225.

Huovila, P. and Koskela, L. (1998). Contribution of the principles of Lean construction to meet the challenges of sustainable development, *Proceedings IGLC'98.*

Hwang, B., Thomas, S., Haas, C. and Caldas, C. (2009). Measuring the Impact of Rework on Construction Cost Performance. *Journal of Construction Engineering and Management*, 135(3), pp.187-198.

Jayasena, H. and Wedikkara, C. (2013). Assessing the BIM maturity in a BIM infant Industry, *The 2nd World Construction Symposium 2013, Colombo, Sri Lanka.*

Jelodar, M., Wilkinson, S. and Tookey, J. (2018). Construction Project Innovation; A System Controlled by Construction Project Dynamics. *Proceedings Cobra 23-24 April, 2018, RICS HQ, London, UK*.

Kalsaas, B. (2012). The Last Planner System Style of Planning: Its Basis in Learning Theory. *Journal of Engineering, Project, and Production Management*, 2(2), pp.88-100.

Khaba, S. and Bhar, C. (2017). Modelling the key barriers to learn construction using interpretive structural modelling. *Journal of Modelling in Management*, 4(12), pp.652-670.

Koskela, L. (1992). Application of the New Production Philosophy to Construction. CIFE, *Technical Report No.72, Stanford, USA*

Koskela, L. 2004, Making – Do – the eighth category of Waste,

Koskela, L. (2004). Moving– on– beyond lean thinking. *Lean Construction Journal*, 1, pp.24-37.

Koskela, L., Ballard, G., Howell, G. and Zabelle, T. (2001). Production System Design: Work Structuring Revisited. *Lean Construction Institute White Paper*, p.14.

Latham, M. (1994). Constructing the Team, Final report of the Government / Industry Review of Procurement and contractual arrangements in the UK construction Industry, *London HMSO.*

Lean Examples in Construction, Report by the Construction Productivity Network, 2003

Luo, Y., Rilley, D. and Horman, M. (2005). Lean Principles for Prefabrication in Green Design-Build (GDP) Projects, Safety Quality and Environmental Management systems, *Proceedings IGLC-13, July 2005, Sydney, Australia.*

Mahfuth, K., Loulizi, A., Al-Hallaq, K. and Tayeh, B. (2019). Implementation Phase Safety System for Minimising Construction Project Waste. *Journal of Buildings*, pp.9-25.

Mossman, A. (2009). Creating value: A sufficient way to eliminate waste in lean design and lean production. *Lean Construction Journal*, pp.13-23.

Nesensohn, C., Bryde, D. and Pasquire, E. (2014), *Assessing Lean Construction Maturity*, Annual conference of the international group for lean construction at Oslo.

Ohno, T. (1988). Toyota Production System, *Productivity Press, Cambridge, MA. p.143.*

Pasquire, C. and Connoly, G. (2002). Leaner construction through off-site manufacturing.

Passer, M. and Smith, R. (2015). *Psychology; The Science of Mind and Behaviour,* 2nd edn, North Ryde, NSW: McGraw-Hill Australia.

Pinch, L. (2005). Lean Construction: Eliminating the waste, Construction Executive. 11, pp.34-37.

Rahaman, H., Wang, C. and Lim, I. (2012). Waste processing framework for Non-value adding activities using lean construction. *Journal of Frontiers in Construction Engineering*, 1, pp.8-13.

Ruan, X., Zuofa, T., Ochieng, E. and Yang, M. (2016). An Appraisal of Lean Construction Project Delivery Application of Lean Construction. *Journal of IEEE*.

Sacks, R., Koskela, L., Dave, B. and Owen, R. (2010). The interaction of lean and building information modelling in construction. *Journal of Construction Engineering and Management,* 136(9), pp.968-980.

Salem, O. and Zimmer, E. (2005). Application of Lean Manufacturing Principles to Construction. *Lean Constructions Journal*, pp.51-55.

Salem, O., Genaidy, A., Luegring, M., Paez, O. and Solomon, J. (2004). The path from lean manufacturing to lean construction: implementation and Evaluation of Lean Assembly.

Salem, O., Solomon, J., Genaidy, A. and Luegring, M. (2005). Site Implementation and Assessment of Lean Construction Techniques. *Lean Construction Journal*, pp.1- 21.

Salem, O., Solomon, J., Genaidy, A. and Minkarah, I. (2006). Lean Construction: From Theory to Implementation. *Journal of Management in Engineering*, 22(4), pp.168-175.

Salvatierra-Garrido, J. and Pasquire, C. (2011). Value theory in lean construction. *Journal of Financial Management of Property and Construction*, 16(1), pp.8-18.

Sarhan, J., Fawzia, B., Karim, A. and Olanipekun, A. (2018). Barriers to implementing lean construction practices in the Kingdom of Saudi Arabia(KSA) construction industry. *Construction Innovation,* 2(18), pp.246-272.

Senaratne, S. and Wijesiri, D. (2008). Lean construction as a strategic option: Testing its suitability and acceptability in Sri Lanka. *Lean Construction Journal*, pp.34-38.

Singleton, M. and Hamzeh, F. (2011). Implementing Integrated Project Delivery on Department of the Navy Construction Projects. *Lean Construction Journal*, pp.17-31.

Smith, L., Jones, I. and Vickridge, I. (1999). Increasing construction productivity through total loss control, *COBRA, RICS Research Foundation*.

Tam, V., Tam, C. and Ng, W. (2007). On prefabrication implementation for different project types and procurement methods in Hong Kong. *Journal of Engineering, Design and Technology*, 5(1), pp.68-80.

Thilakarathna, N. and Senaratne, S. (2012). Literature Review into Lean Construction Implementation, *Proceedings CIOB June 2012, Colombo*.

Thilakarathna, N. and De Silva, L. (2018). Tool for Assessing Lean Maturity in Construction Projects in Sri Lanka. *Proceedings the 7th World Construction Symposium, 29 June- 01 July 2018, Colombo, Sri Lanka.*

Thomsen, C., Darrington, J., Dunne, D. and Lichtig, W. (2010). Managing Integrated Project Delivery, *CMAA 7926 Jones Branch Drive, Suite 800, McLean.*

Tzortzopoulos, P. and Formoso, C. (1999). Consideration of application of Lean construction principles to Design Management; *University of California, Berkeley, CA, USA.*

Vilashini, N. and Neitzert, T. (2012). Appropriateness of Lean Production System for the Construction Industry. *World Construction Conference 2012 – Global Challenges in Construction Industry, 28-30 June 2012, Colombo, Sri Lanka.*

Vilasini, N., Neitzert, T. and Gamage, J. (2011). Lean methodology to reduce waste in a construction environment. *Symposium conducted at the meeting of the 15th Pacific Association of Quantity Surveyors Congress, Sri Lanka*.

Vilasini, N., Neitzert, T. and Gamage, J. (2011). Lean methodology to reduce waste in a construction environment. *15th Pacific Association of Quantity Surveyors Congress 23-26 July 2011, Colombo, Sri Lanka*.

Vilasini, N., Neitzert, T. and Rotimi, J. (2011). Correlation between Construction Procurement Methods and Lean Principles. *International Journal of Construction Management*, 11(4), pp.65-78.

Vilasini, N., Neitzert, T. and Rotimi, J. (2014). Developing and evaluating a framework for process improvement in an alliance project: a New Zealand case study. *Construction Management and Economics*, 6(32), pp.625-640.

Womack, J. P., and Jones, D.T., (2003), Lean Thinking. New York: Simon and Schuster

Zimina, D., Ballard, G. and Pasquire, C. (2012). Target value design: using collaboration and a lean approach to reduce construction cost. *Construction Management and Economics*, 30(5), pp.383-398.