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Lean Construction and Value Based Approaches for Optimizing Design and Construction Effectiveness in Built Environment Practices

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Abstract:
Construction waste remains a critical concern in modern construction processes. Lean construction seeks to provide viable solutions in current sustainability considerations. The paper examined lean construction approaches adoptable in architecture and construction project processes from an integrative approach. The concepts are defined, while attempts are made at explaining its methodological application in the construction process and enlightening on its benefits toward the improvement of modern construction practices. Especially, in the face of constantly evolving challenges and perpetually turbulent environments there is a need to further strengthen seemingly appreciable approaches for achievable resilience.

Keywords: *Lean construction, target value, waste reduction*

1. Introduction

1.1. Background to the Study

Construction cost was estimated to grow globally by sixty seven percent (67%) from $7.2 trillion to $12 trillion by 2020 as the industry expands (AEC, 2012). This is inclusive of costs of waste recorded by the industry. Of this figure, the United States singularly records over a colossal $120 billion annually due to cost overruns, control delays and other inefficiencies. This has raised many concerns on the viability of the industry in the long term. Hence, there are desperate attempts at finding lasting solutions to effectively tackle this growing problem by reducing costs while increasing efficiency. This has led to the creation of systems, techniques, and methods in practice across all stages of the architectural process from the design to the on-site construction. Lean construction is one of the methods birthed by these concerns and is rapidly gaining popularity. Lean construction has become a process now widely employed by construction practitioners universally as claims are being made that it presents a recognizable positive effectiveness in practice. McGraw Hill (2013) presents that among contractors using the Lean construction methods in a year 2011 study, 84% recorded higher quality construction, 80% recorded greater customer satisfaction, 77% noted greater productivity, and improved safety was highlighted by 77%. They further present that despite these statistics, 55% of firms in the industry remain unfamiliar with lean practices and regard normal construction practices as efficient, disappointingly. This highlights an existent lack of knowledge concerning lean practices among practitioners thus defining a need for enlightenment if the desired aim of directing the practice in a more profitable, as well as innovative direction should be achieved. Consequently, the intricate nature of Lean Construction is thus discussed.

1.2. Aim and Objectives

The aim of the study is to highlight existing lean construction strategies available in practice which could promote logical management of resources in built environment practices. The underlying objectives involved reviewing the strategic targets of the lean construction initiative, appraising the various practicable lean construction alternatives, interpreting interactions between lean construction and contemporary construction processes and investigating the considerations for safety in the lean definitive approaches. The practicable benefits recognizable with lean construction approaches in real-time practice are also considered.

2. Research Methodology

The study takes an exploratory and discursive approach towards understanding the Lean construction concept. Exhaustive reviews of lean related literature, theories and recorded data from real time practice based experiences is are undertaken. Case study reviews and a necessary critique of the viability of lean construction frameworks is done in a logical manner to clearly elicit the direction of the concept.

3. Literature Review

3.1. Lean Construction and the Development of the Concept

According to McGraw Hill (2013), 'Lean construction' refers to the elimination of waste from the processes of designing and constructing buildings. The context of Lean construction is concerned with aligning to current and continuous improvements in every ramification of the built environment including design, construction, maintenance, salvaging and recycling (Abdelhamid et al, 2008). Koskela et al (2002) describes the concept as an approach which considers customers' needs primarily and attempts to manage and improve construction processes by reducing cost and waste while generating maximum value. Lean construction is a combination of operational research and practical development in design and construction with an adaptation of lean manufacturing principles to the end to end design and construction process. Lichtig (2004) confirms that lean construction identifies that desired ends influence the means through which these ends are achieved and that the available means will affect realized ends. The concept of Lean originated from the automotive industry, specifically from Toyota's Production System (TPS). Established by Womack et al, the focus of lean thinking discovery was to eliminate waste resulting from human activity which absorbed resources but did not create value (Womack and Jones, 1996). However, their initial dimension of discovery tailored primarily to the manufacturing sector which varies greatly to the construction industry. There was thus a need for a perspective relative to construction practices. Koskela (1992) made a pioneering attempt at interpreting lean thinking in relation to construction challenging practitioners in the industry to review the shortcomings of the cost, quality and time relationship. Consequently, this led to the formation of a group that would be subsequently concerned with Lean practices in construction.

The birth of the term 'Lean Construction' as Gleeson et al (2007) present was originated by the International Group for Lean Construction at its first meeting in 1993. Emphasis lent that the term considered construction not just as a phase, but with reference to the entire industry and as such concerns all construction professionals, architects, designers, engineers. Salem (2006) established that there is a need to distinguish lean construction from lean manufacturing as both are executed in totally opposite environments and under different uncertainty levels. Ballard and Howell (1994) in analyzing the failure of project plans made another observation that only about 50% of weekly work plans were accomplished by the weekend. They further noted that this could be alleviated if there was active management of variability from the project structuring, through its operation and improvement.

Abdelhamid (2004) like Koskela (2000), argued that the recurrence of negative experiences on projects leading to poor results, and the failure of existent construction planning and management tools and techniques demanded for a review of the construction management principles and possibly, the development of a theory of production in construction. Koskela thence adopted the ideal production system which formed a part of the Toyota Production System (TPS) on which he established an all-inclusive production management model for project based-production, where production is conceived in three corresponding dimensions viz: Transformation (T), Flow (F) and as Value (V) generation. '*Transformation*' is regarded as the conversion of inputs to outputs. Flow is considered as a smooth, uninterrupted movement in work momentum from one crew to the next or the flow of value at the pull of the customer. This is one of the core elements of lean concepts towards eliminating waste totally. It connects with the logic of flowing value without interruption. However, this remains a huge challenge in construction sites as activities are of a fragmented nature and products of construction are very dissimilar most times (Koskela, 2000). A work flow study on 3 bridge construction sites was undertaken by Randolph Thomas et al (2003) who identified that work hours consumed by labour/workmen totaled at 12,063 hours across the 3 sites. However, it was also discovered that 4,601 hours out of these were dedicated to reworking, batching and queuing and other inefficiencies. This signifies high wastage statistics and very poor effectiveness which lean construction seeks to correct.

Value refers to the expected product of the project which the customer is actually paying for. According to Picchi and Granja (2006) the starting point in applying Lean thinking should be the understanding of how value is perceived from the client's point of view. This perception should include critically defining the main characteristics of the product and the benefits the client is willing to pay for. This is a primary step in waste recognition. Alves and Formoso (2000) suggest that managing the flow of materials, people and equipment in construction sites must be considered an important part of the production planning and control process. Ballard et al (2002) analyzed the fabrication of precast concrete using a process flow map, and that culminated in identifying opportunities of using flow and pull lean techniques. Tommelein and Li (1999) considered the value stream of ready-mix concrete with respect to batching and delivery and identified that the concrete supply chain could be improved toward a Just-In-time (JIT) lean approach. Koskela and Howell (2002) further proffered an analysis of existing management theories particularly associated with planning, execution and control concerns in project based production systems. Abdelhamid (2004) asserts that these dire concerns provide a solid intellectual base for the need Lean Construction in practice.

3.2. Lean Construction Principles and Tools for Strategic Implementation

Abdelhamid (2007) suggests that the concept of lean construction requires a proper interaction between project and production management for any project undertaking to be successful. It thus draws upon a mix of both the principles of project level management as well as production level management principles. Lean construction supplements traditional construction management approaches by exploring two critical and necessary dimensions for successful capital project delivery by requiring the deliberate consideration of material and information flow and value generation in a production system. It also adopts different project and production management (planning-execution-control) paradigms. Predictable and reliable flow of work on a construction site requires the perfect alignment of the entire supply chain responsible for constructed facilities such that value is maximized and waste is minimized. Considering this wideness in scope, tools employed in Lean Manufacturing and Production as with Toyota are currently adapted to use in achieving lean construction principles. These include Total Quality Management (TQM), Six-sigma (6S) and Statistical Process Control (SPC). Also social science and business tools and methods have been adopted in construction management implementations where necessary, with these tools inclusive of the Critical Path Method (CPM), and Work Breakdown Structure (WBS). However, the three unique tools, systems and methods specifically conceived for lean construction include: The Last Planner System, Target Value Design, and The Lean Project Delivery System. Mastroianni and Abdelhamid (2003) and Salem et al (2005) amongst many others, consider that the Last Planner System remains the main tool employed in lean construction processes for achieving predictable outcomes. Tool kits or techniques which constitute some of these systems include: choosing by advantage (CBA), Building Information modeling - BIM (Lean Design), off site fabrication and Just-In-Time (Lean Supply), Value Chain Mapping (Lean Assembly), and Daily Crew Huddles (Lean Assembly).

Certain principles commonly identified as shared by the Lean Construction tools include: Optimization of the whole system through Collaboration and systematic learning, Focus on delivering client desired value, Systematically eliminating obstacles to value creation such that value flows easily, Creating pull production, Continuous improvement and pursuit for perfection while involving everyone in the system.

3.3. The Last Planner System (LPS)

Developed by the Lean Construction Institute, the last planner system refers to 'a collaborative commitment-based planning system that integrates should-can-will-did planning (pull planning, make ready, look-ahead planning) with constraint analysis, weekly work planning based upon reliable promise, and learning based upon analysis of plan percent complete and reasons for variance, (LCI)'. LPS is a system of inter-related elements and is based on simple paper forms hence it can be administered using paper and pencil or spreadsheets. Elements of the Last planner System include: Collaborative Programming, Make-Ready, Production Planning, Production Management and Measurement, Learning and Continual Improvement (Mossman, 2013).

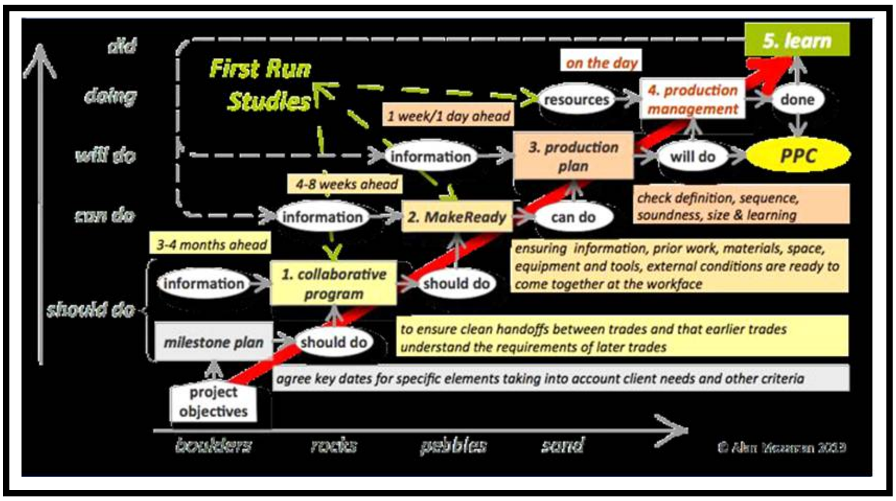

Figure 1: The Last Planner System as a Flowchart
Source: Mossman, 2013

Collaborative programming involves the creation and agreement on the project production sequence. Typically the LPS would begin with collaborative scheduling and programming where key assumptions will be made and an analysis of risk ensures the incorporation of float, slack or padding for protection of project integrity and predictability. Since the LPS is a program coordination and production control system designed to ensure achievement of agreed goals, the collaborative programming mindset requires that all main suppliers and specialist contractors are involved from the onset in preparing both the master program and program for each new phase. The collaborative programming process can also be used for project compression.

The Make-Ready constituent involves the preparation of tasks by team leaders in good time so that work is done when it should be done. It involves the use of a tick sheet, systematically checking that everything is in place for look-ahead tasks. The make-ready should be continuous throughout the project. For Production Evaluation and Planning, a weekly work planning (WWP) meeting involving all the last planners (i.e., team leaders, and on-site supervisors) is necessary for enlightenment of task inter-dependencies and identifying task boundaries. This also provides for a review and learning from previous and current work. The WWP process is mainly based on promises, where an agreed program defines when tasks should be done and acts as a request to the supplier to execute the task. The last planners can only promise after clarification that the task is executable and that conditions are satisfactory.

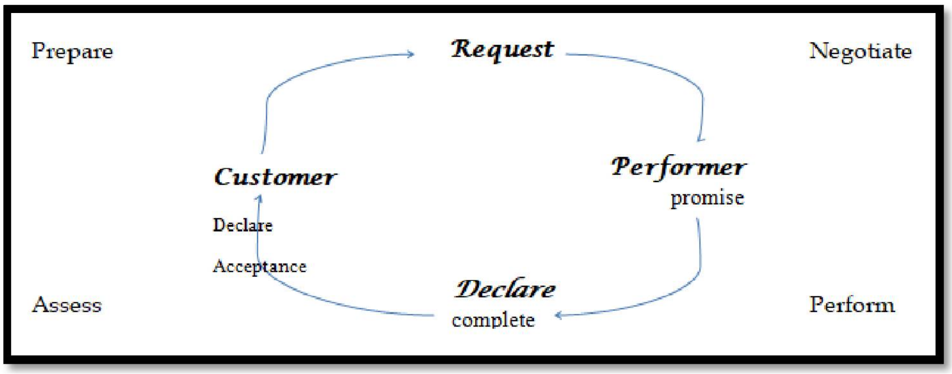

Figure 2: The Promise Cycle as Developed by Fernando Flores
Source: Mossman, 2013

Production Management considers that ***o**n* completion of the task, the last planner responsible asserts completion then site management undertakes an assurance check that it is complete to appropriate standards. While for Measurement, Learning and Continual Improvement, the Percentage of Promises Completed (PPC) on time is a key measure of success in the last planner system. As the PPC increases, project productivity and profitability also increase with an estimated 70% to 85% difference. Scores are measured site-wide and openly displayed. Understanding the reasons why tasks promised in the WWP are delivered late is a major part of the continuous improvement process. Reasons are usually recorded in a Pareto chart so it makes it easier to recognize areas needing more attention to yield results. Mossman (2013) further enlightens that though widely used in practice, it is important to note that just using Last Planner system is not lean as Last Planner is a tool like most other tools used in lean transformations that considers lean thinking about a very specific problem.

3.4. Appraising the Target Value Design System (TVD)

Cost, time, location and other constraints are conditions that must be met in order 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. Implementation of TVD has consistently resulted in the delivery of projects faster and under budget, both against market benchmarks and project targets. Consequently TVD is both a method that assures customers get what they need (delivers value) and also a method for continuous improvement and waste reduction. It is a common occurrence experienced by every contractor where a project design for whatever reason, exceeds the owner's budget. Where there is no allowance to spend more the contractor has little choice but to value engineer the design down to size. Some value engineering decisions are relatively easy, others aren't. Although the result may satisfy the owner's pocketbook, not everyone perceives value engineering the same way. Rationalizing a successful project outcome that pleases few people does not seem entirely acceptable either.

The advent of Lean construction and Integrated Project Delivery (IPD) practices have gone a long way toward narrowing budget driven differences that can necessitate value engineering. Having all participants actively involved and communicating from the outset often yields far more consensus than conflict about what actually gets built. Still, gaps usually exist between what is wanted and what is affordable in capital construction. The latest IPD iteration, target value design (TVD), offers the potential to ensure that owners get what they pay for and possibly more. Rather than designing first and estimating later, TVD pegs a project's validated estimated cost as the starting point. Targets are established for all relevant components (e.g., building envelope, structural system, interior finishes, mechanical, electrical and plumbing systems, etc.), and then they are adjusted up or down collaboratively by cross disciplinary teams as the design evolves. But cost is only one component of TVD. The project team also sets and designs toward other owner established targets such as sustainability, staffing, square footage, operations and lifecycle costs. As the TVD process progresses, various options and their effect on other parts of the project are continually considered and discussed within the context of the overall project. Dick Bayer, interim executive director of the national nonprofit Lean Construction Institute (LCI), which works to reform management of production in capital facilities design, engineering and construction, calls TVD a very robust process to cut out contingencies and waste and drive efficiencies without sacrificing quality. Although cost certainty is a key outcome in TVD, Dean Reed, lean coordinator for DPR Construction Inc., San Francisco, says it's a mistake to think that cost drives design. Reed explains that typical conversations between designers and builders often suggest that most times cost informs design.

Victor Sanvido, president of Garden Grove, California based mechanical contractor Southland Industries and chair of LCI's national board argues that it is impending that contractors drive the process as their knowledge is what enables the team to control the design and achieve the balance of selecting the right systems at the right price. While all members of a team bring valuable perspectives to TVD, contractors' role is pivotal as they continually provide estimates and constructability insights, resulting in more informed realistic design decisions. Risk of owner or design team expectations which could be unrealistic can be reduced through contractor involvement. Despite its short existence TVD has cut an impressive trail record across projects of varying nature compared to other different project delivery approaches.

Mark Konchar, the vice president of national integration for Leading International Infrastructure group, Balfour Beatty PLC asserts against general advocacy that TVD has a place in every project that instead, the success of TVD depends on the right environment. An open-mindedness and willingness to commit to lean construction practices on the part of the client or owner is required early enough for identification of best tools and approaches for the project. Understanding what value means to the owner is critical for contractors towards interpreting how it can be influenced for value to be added. Accepting critiques and alternating perspectives should be considered as important as offering lessons learned from past project experiences. In practice, TVD processes may require changes when applied to different owners and facility types. Nonetheless, more common applications of the approach will involve deeply engaging with the client to establish the target-value and continually unravel client concerns in the course of the design process. The responsibility for revealing and refining concerns, constructing new assessments of what value is and for selecting how that value is produced is shared by designer and client alike. Also expectations that the team will learn and create unanticipated results while instituting routines to make known what has been learned or innovated real-time is non-negligible. Such surprises could upset existing plans and result in need for re-planning, hence the need for effective leadership of design efforts for learning and innovation. Evaluating design against budget and the target values of the client using necessary mechanisms is crucial and design should be done to a detailed estimate, with consistent review against targets. Learning and innovation arises socially so it advisable to work in small and diverse groups to create a conducive environment for establishment of trust, care and communication. Impromptu sessions among design team members are a necessary part of the process. These are considered basic foundational practices which when taken together, establish a base for adopting other lean design practices.

3.5. Lean Construction and Contemporary Construction and Architectural Project Management Approaches

Howell (1999) asserts that a primary concern of lean construction is how the interaction between activities and combined effects of variation and dependence is managed as this has an immense influence on project time and cost considerations. Concerns which he argues are lacking in PM approaches. For Ballard (2000) while PM approaches focus on improving productivity on single task activities, Lean construction considers reliability of work flow thereby making effectiveness a continuous consideration across tasks. While the total project is managed as a value generating process and the product the value the customer pays for in the Lean construction perspective, PM approaches generally consider less cost or expenditure as increased value, (Howell, 1999). Transparency forms an inherent part of Lean construction processes as stakeholders, managers and employees can collectively view the impact of their work throughout the project, Ballard (2000) suggests that this is not evident in PM approaches. Also, while PM approaches pay little attention to continuous improvement, Lean approaches strive to make continuous improvements in the process, workflows and product. A visible attempt is made at mitigating variation in every concern and managing the little that remains, in Lean construction practice.

3.6. Safety Considerations in Lean Construction Initiatives

In Lean conceptions, poor safety is interpreted a form of waste as injuries or in death extreme cases are costly not only in terms of human suffering but also in terms of worker compensation costs, lost time, lost productivity, and higher employee turnover. Safety is therefore an imperative factor to incorporate into process and production plans, in order to achieve projected goals of improved worker health, reduced costs, and increased value. Earlier in history, very few endeavors in production processes considered safety critically. However repeated studies over time unravel safety is an integral part of every production process irrespective of the anticipated product. Thus more recently it has become a priority that safety is dependent on every action, material, and person involved in production processes. Work processes in a construction project are inherently safe or hazardous according to the safety hazards present in each step required to complete a process. Koskela (1992) enlists that levels of safety performance depends on the nature of the job and must be continuously maintained and improved as part of those processes by carefully planning processes to minimize safety risks thus making work less hazardous.

Mitropoulos et al. (2007) consider guidelines on how to combine Lean principles with safety initiatives in the workplace. In response to the lack of guidance, two possible scenarios are proposed for explaining how Lean production practices may affect safety through the use of continuous improvement (CI) programs. Firstly, CI programs will reduce opportunities for accidents through reduced waste (in material usage and elimination of dangerous process steps) and therefore reduced safety hazards. Secondly, CI programs can include safety initiatives as one category of improvement projects undertaken. In the first scenario, the conscious effort toward continuous improvement through the reduction of waste in materials and processes may result in reduced opportunities for accidents. The inherent practice of continuous improvement drives safety improvements without the explicit integration of specific safety programs. The pathway to safety outcomes from CI programs passes only through Lean construction. In practice, construction projects with best safety performances are likely to use good scheduling and housekeeping practices, which are main tenets of Lean production (Veteto 1994, Mattila et al. 1994). Using two principles of Lean, reducing waste and increasing efficiency, often result in a reduction of process steps, materials used, and motions required. These reductions in turn will reduce the probability of incurring an accident or coming in contact with hazardous materials. Reducing materials and time to completion will decrease exposure to hazardous chemicals, excessive noise, biomechanical hazards, and other industrial hygiene hazards. For example, by reducing the number of times a heavy object is lifted and handled, the total time needed to complete a process is reduced (improved efficiency) and the risk of back injury is also reduced. Improved housekeeping, which is another tenet of Lean production, will also reduce hazards such as chemical exposures and tripping/falling hazards.

The second scenario involves safety programs becoming a part of Lean practices. Safety programs can be integrated with Lean through incorporation in CI programs. Outcomes are realized from CI programs through the interaction with safety programs and initiatives. Nishigaki et al. (1992) proffers that in construction, the working environment constantly changes among projects, so safety performance is ultimately dependent on the avoidance of unsafe acts by workers. This findings stress the importance of having all employees involved in safety planning. Lean practitioners have a designated responsibility to create opportunities for team work and continuous improvement in normal operations.

Decisions regarding the elimination and control of safety hazards can be incorporated into Lean planning activities. The first step is to determine if the hazard can be eliminated completely or if it must be controlled. If the hazard cannot be eliminated, the second step is to determine how the hazard can be controlled, either through engineering controls, administrative changes, personal protective equipment (PPE), or some combination of these three alternatives. Engineering controls are widely considered the most effective, although often most costly, while PPE are considered the least effective (Friend and Kohn 2007). In reality, PPE are often used in conjunction with engineering and administrative controls when these preferred methods cannot reduce the hazard to an acceptable level. Lean processes may automatically address many safety hazards from the elimination (through reducing steps, exposures, etc.) and engineering control perspectives through process designs. The critical evaluation of processes that occur through Lean will also benefit safety if safety concerns are incorporated as part of the evaluation process. Any concerns identified that cannot be completely resolved through process design will then become candidates for administrative or PPE controls, which may also be considered through continuous improvement activities.

3.7. Integrating Safety in Lean Construction

The creation of a culture within the company of continuous improvement is one of the focuses of Lean Construction. Diekmann et al. (2005) acknowledged five major Lean principles applicable in the housing industry: customer focus, culture/people, workplace standardization, waste elimination and continuous improvement/built-in quality. Furthermore, Diekmann et al. (2005) suggested that CI programs can be used as a guide for creating a construction organization that moves closer to the ideal of Lean production. Koskela (1993) concluded that the implementation of Lean production concepts into construction seems to be a major factor in the endeavor to eliminate accidents. Koskela identified strategies to improve construction safety through the use of Lean production concepts: Designing, controlling and improving engineering and construction processes to ensure predictable material and work flow on site; Improving safety management and planning processes themselves to systematically consider hazards and their counter measures; Improving safety related behaviors- instituting procedures that aim at minimizing unsafe acts.

Lean principles may be used to support safety programs in industrialized housing manufacturers by increasing safe behavior (and thereby reducing injury rates), and safety in turn can be integrated into Lean processes. However, the proposed benefit of improved safety through the use of Lean production (Saurin et al. 2006, Koskela 1992, 2000) has not been measured empirically. Nahmens and Ikuma (2009) suggest that several fundamental research questions in lean construction and safety considerations still remain largely unanswered. These include questions on whether the implementation of Lean principles directly result in improved construction safety, and whether Lean and safety principles be combined to develop a framework for improving processes and safety simultaneously.

Following a research study, Thomassen et al. (2003) reports a successful reduction of safety incidence rates by 45% by using Lean Construction tools such as Last Planner (LP) and other planning tools. The incorporation of other Lean Construction tools such as 6-Sigma and LP should be studied from the perspective of safety improvements in the industrialized housing industry to determine if a more complete implementation of Lean Construction results in further safety improvements beyond those found with CI programs. If these results do find links between safety and Lean Construction, a model of how to incorporate safety initiatives into a culture of Lean will be highly valuable to management and will strengthen the case for using Lean Construction (Nahmens and Ikuma, 2009).

3.8. Practicable Benefits of Lean Construction

Pinch (2005) and Marhani et al (2012) reviewed cases were lean approaches improved construction processes optimally highlighting success. Lean strategies were introduced at the architectural and construction phases of a 158 bed hospital healthcare project and this immensely reorganized and re-engineered the project for better benefits (Pinch, 2005). Maximization of profit was recognized with a cost reduction of up to twenty-five percent on the project **as *r***eal time project status aided in the identification of tasks which could cause loss of profit. This evidences that there is a link to procurement which enhances cost control. Better measurement of work breakdown and completion times will result in Earned Value approach. This coupled with prefab delivery results in earlier payment thus improving cash flow. Adopting building information modeling technologies (BIM) and other 3D visualization techniques result in clear understanding of a complex project through a common language. Workers at all levels can understand their specific role and how that fits in the grand design. Achieving minimization of waste with an executable and reasonable plan based on the real state of the project in real time will become possible. Reduction of possible hazardous processes in turn results in increased safety probability creating room for full achievement of project outcomes with stipulated timelines and evasion of impending accident related costs in project environments.

4. Conclusion

A wide cross section of Lean construction practitioners attest to its effectiveness, product driven approach and high cost reduction/ waste eradication attributes, resulting in increased productivity and profitability. However, there still remains a substantially equivalent amount of practitioners oblivious to the existence of Lean Construction approaches, thus greater advocacy must be made toward publicizing the Lean thought. Also, more research needs to be done to bring it to its simplest terms such that it can be easily adapted to in practice. Climes where challenges to overall development and general infrastructure which could present easier adoption and implementation of lean approaches in building construction exist, particularly present unique challenges.

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