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Lean Thinking Principles Applied in Construction Industries

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Abstract- **Productivity is the concern for the construction industry form last 5 decades. Past research showed that the lean construction has an ability to solve this issue. Lean construction results from the application of a new form of production management to construction. Necessary features of lean construction include a clear set of objectives for the delivery process, aimed at maximizing performance for the customer at the project level, concurrent design, construction, and the application of project control throughout the life cycle of the project from design to delivery. An increasing number of construction academics and professionals have been storming the battlements of conventional construction management to deliver better value to owners while making real profits. As a result, lean-based tools have emerged and have been successfully applied to simple and complex construction projects. In general, lean construction projects are easier to manage, safer, completed sooner, and cost less and are of better quality. Significant research remains to complete the translation to construction of lean thinking in India. This research will discuss principles, methods, and implementation phases of lean construction showing the waste in construction and how it could be minimized.**

Index Terms- **Productivity, Lean, Performance**

I. INTRODUCTION

Since the 1950s, lean production or Toyota production system principles have evolved and were successfully implemented by Toyota Motor Company. Toyota production system had two pillar concepts:

Just In Time flow (JIT) and Automation (smart automation). The term ‘‘lean’’ was coined by the research team working on international auto production to reflect both the waste reduction nature of the Toyota production system and to contrast it with craft and mass forms of production [2].

Starting from efforts to reduce machine setup time and influenced by TQM, a simple set of objectives was developed for the design of the production system including to (1) Identify and deliver value to the customer value: eliminate anything that does not add value; (2) Organize production as a continuous flow; (3) Perfect the product and create reliable flow through distributing information and decision making; and (4) Pursue perfection: Deliver on order a product meeting customer requirements with nothing in inventory. Lean production aims to design and make things differentiated from mass and craft forms of production by the objectives and technique, and to optimize performance of the production system against a standard of perfection to meet unique customer requirements. In the beginning of the 1990s, the new production philosophy, which is known by several different names, is as follows: (1) world class manufacturing; (2) lean production; and (3) new production system. This philosophy is the emerging mainstream approach. It is practiced, at least partially, by major manufacturing companies in America and Europe. The new approach has also diffused to new fields, like customized production, services, administration, and product development.

Since 1992, Koskela [3] has reported the adaptation of lean production concepts in the construction industry and presented a production management paradigm where production was conceptualized in three complementary ways, namely as (1) Transformation; (2) Flow; and (3) Value generation (TFV) theory of production. This tripartite view of production has led to the birth of lean construction as a discipline that subsumes the transformation-dominated contemporary construction management [4,5].

Managing construction under lean is different from typical contemporary practice because it (1) has a clear set of objectives for the delivery process; (2) is aimed at maximizing performance for the customer at the project level; (3) designs concurrently product and process; and (4) applies production control throughout the life of the project. The first goal of lean construction must be to fully understand the physics of production, the effects of dependence and variation along supply and assembly chains. In lean construction as in much of manufacturing, (1) Planning: defining criteria for success and producing strategies for achieving and (2) Control: causing events to conform to plan, and triggering earning and re-planning are two sides of a coin that keeps revolving throughout a project. In this research, principles ,methods, and the implementation phases of lean construction will be discussed showing the waste in construction and how it could be minimized.

II. RESEARCH BACKGROUND

Construction management and technology are the two key factors influencing the development of the construction industry. Over the past 43 years, although several new and advanced technologies have been applied to construction projects, the efficiency of the industry has remained quite low [6–8]. For example, the productivity of the USA

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construction industry has been declining since 1964 [9]. A similar decline in construction productivity has also occurred in other countries. Japan, for example, decreased from 3714 to 2731 Yen/Man/Hours over the period of 1990–2004. The main reason for this appears to be that the new technologies cannot effectively reduce the cost of design and construction while, at the same time, improving the management of the construction process. For example, although the Computer Aided Design (CAD) technology has improved the efficiency of drawing, it cannot reduce design errors and these, in turn, can cause the need for rework of construction making it difficult for construction managers to optimize the construction process to reduce cost [10,11].
This is a particularly relevant issue for Design/Build (D/B) projects, where the aim is to reduce cost and increase quality by an improved constructability of the building design. However, the new technologies cannot, as yet, effectively support the implementation of D/B projects. Therefore, the application of both appropriate new technology and contemporary management concepts is likely to be two effective approaches to improve construction industry efficiency. One of the new management philosophies that have been considered for the UK construction industry is that of lean thinking [12]. Lean construction, much like current practice, has the goal of better meeting customer needs while using less of everything, a term coined by the International Group for Lean Construction in 1993, Gleeson and Townend [13] had been investigated by many researchers in recent years. This refers to the application of lean production principles and practices in design–construction processes to maximize value and to reduce waste [14,15]. Some successful experience in implementing lean construction has been achieved. Conte and Gransberg [16], for example, examined the principles used in applying lean construction by over 20 construction companies in Brazil. Similarly, Wright [17] presented several cases involving the use of lean construction. However, the application of lean construction is still in its initial stages. In order to improve the implementation of lean construction, Miller et al. [18] proposed the harmonization between main contractors and subcontractors as a prerequisite, while Thomas et al. [19,20] proposed reducing variability to improve performance and improving labor flow reliability for better productivity as lean construction principles.

III. RESEARCH OBJECTIVES

As a response to the construction problems previously discussed, the research seeks to confirm the following objectives: (1) Determine the implementation of lean ideal; (2) Identify the source of wastes classified under lean construction industry; (3) Examine general perceptions of the construction industry with the lean construction principles of practices.

IV. LEAN JOURNEY

Lean implementation begins with leadership commitment and is sustained with a culture of continuous improvement. When the principles are applied properly, dramatic improvements in safety, quality, and efficiency can be achieved at the project level. Improvements at the process and enterprise levels are enablers that make improvements at the project level more successful and allow such improvements to be sustainable [21]. The lean ideal is to provide a custom product exactly fit for purpose and delivered instantly with no waste to the subsequent actions that may be necessary in order for projects to pursue that ideal [21]. The ability of individuals and organizations to follow this process will vary with position and circumstances, but to the extent possible, the following should be implemented on projects: (1) Select suppliers who are willing to adopt lean project delivery; (2) Structure the project organization to allow money to move in pursuit of the best project level returns; (3) Define and align project scope, budget, and schedule; (4) Explore adaptation and development of methods; (5) Make design decisions, with explicit alternatives against stated criteria; (5) Practice production control in accordance with lean principles; (6) Build quality and safety into projects; (7) Implement JIT and multi-organizational processes after site demand; (8) Use evaluations and planning on process that transform materials; (9) Use computer modeling to integrate product and process design; (10) Use 5S workshops: a tool for workplace organization and promoting teamwork (S1) Sort through items, keep what is needed and dispose of what is not; (S2) Straighten: organize and label everything; (S3) Shine: clean; which can also expose abnormal and pre-failure conditions; (S4) Standardize: develop rules to maintain the first three S's; and (S5) Sustain: manage to maintain a stabilized workplace and initiate continuous improvement when needed and (11) Apply Value Stream Mapping to make visible all the steps in process. These can be organized specially for projects and preceded by a pre-project phase [21].

V. CONSTRUCTION WASTES

Construction management suffers many problems and the majority is practical which need to be solved or better understood. As a result, the construction industry is overwhelmed by delay and often has suffered cost and time overrun. Alsehaimi and Koskela [22] reported that the poor project management was a dominant and common reason for delay in construction projects. Consequently, these problems associated with management, in particular, should be understood, and efforts need to be directed toward developing solutions and more efficient methods of operation. The introduction of new production philosophies in construction requires new measures of performance Koskela [3], such as waste, value, cycle time or variability. UK studies indicated that up to 30% of construction is rework, only 40–60% of potential labor efficiency, accidents can account for 3–6% of total costs, and at least 10% of materials are wasted. The cost of rework in Australian construction projects has been reported as being up to 35% of total project costs and contributes as much as 50% of a project's total overrun costs. In fact, rework is one of the primary factors contributing to the Australian construction industry's poor performance and productivity . In general, a very high level of wastes/non-value added activities is assumed to exist in construction, and it is difficult to measure all waste in construction. Several partial studies from various countries have confirmed that wastes in construction industry represent a relatively large percentage of production cost. The existences of significant number of wastes in the construction have depleted overall performance and productivity of the industry, and certain serious measures have to be taken to rectify the current situation. Waste measures are more effective to support process management, since they enable some operational costs to be properly modeled and generate information that is usually meaningful for the employees, creating conditions to implement decentralized control. ‘‘Anything different from the absolute minimum amount of resources of materials, equipment and manpower, necessary to add value to the product.’’

In general, any losses produced by activities that generate direct or indirect costs but do not add value to the product from the point of view of the client can be called ‘‘waste.’’ Waste is measured in terms of costs; other types of waste are related to the efficiency of the processes, equipment or personnel, and are more difficult to be measured because the optimal efficiency is not always known. Value adding and non value adding activities can be defined as follows: (1) Value adding activities: Those which convert materials and/or information in the search to meet client’s requirements and (2) Non value adding activities (waste): Those which are time, resource, or space consuming, but do not add value to the product. Waste in the construction industry has been the subject of several research projects around the world in recent years. However, most studies tend to focus on the waste of materials, which is only one of the resources involved in the construction process. This seems to be related to the fact that most studies are based on the conversion model, in which material losses are considered to be synonymous of waste.

Many people in the industry have considered wastes are directly associated with the debris removed from the site and disposed of in landfills, and they suggested that the main reason for this relatively narrow view of waste is perhaps the fact that it is relatively easy to see and measure. The main focus for those conventional material waste studies in construction is seen to be restricted to physical waste or material waste in construction and/or the specific impacts due to the physical waste itself.

Various studies, done by other researchers around the world on the wastes in construction, into two main aspects based on the impacts of the construction waste: (1) Researches and studies mostly focused on the environmental impacts that result from the generation of material waste, aimed to reduce the generation of waste at source and to propose alternative methods for treatment of construction waste in order to reduce the demand for final disposal areas, others concerned with the measurement and prevention of construction waste, regarding sustainability requirements stated by Dutch environmental policies; (2) Researches and studies mostly concerned with the economic impacts of waste in the construction industry and concluded that there was a considerable amount of waste that can be avoided by adopting relatively simple prevention procedures. Other researches also pointed out that storage and handling were major causes of waste, while most of the problems concerning waste on building sites are related to flaws in the management system and have very little to do with the lack of qualification of workers. Basically, Koskela [3] has been looking for the evidences of waste and value loss due to (1) Quality of works; (2) Constructability; (3) Material management; (4) Non-productive time; and (5) Safety issues.

Main classification of waste based on the analysis of some Brazilian building sites they had carried out as

(1) Overproduction: related to the production of a quantity greater than required or earlier than necessary. This may cause waste of materials, man hours, or equipment usage. It usually produces inventories of unfinished products or even their total loss, in the case of materials that can deteriorate. An example of this kind of waste is the overproduction of mortar that cannot be used on time;

(2) Substitution: is monetary waste caused by the substitution of a material by a more expensive one (with unnecessary better performance); the execution of simple tasks by an overqualified worker; or the use of highly sophisticated equipment where a much simpler one would be enough;

(3) Waiting time: related to the idle time caused by lack of synchronization and leveling of material flows and pace of work by different groups or equipment. One example is the idle time caused by the lack of material or by lack of work place available for a gang.

(4) Transportation: concerned with the internal movement of materials on site. Excessive handling, the use of inadequate equipment or bad conditions of pathways, can cause this kind of waste. It is usually related to poor layout and the lack of planning of material flows. Its main consequences are as follows: waste of man hours, waste of energy, waste of space on site, and the possibility of material waste during transportation.

(5) Processing: related to the nature of the processing (conversion) activity, which could only be avoided by changing construction technology. For instance, a percentage of mortar is usually wasted when a ceiling is being plastered.

(6) Inventories: related to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery, and vandalism) and monetary losses due to the capital that is tied up. It might be a result of lack of resource planning or uncertainty on the estimation of quantities.

(7) Movement: concerned with unnecessary or inefficient movements made by workers during their job. This might be caused by inadequate equipment, ineffective work methods, or poor arrangement of the working place.

(8) Production of defective products: it occurs when the final or intermediate product does not fit the quality specifications. This may lead to rework or incorporation of unnecessary materials to the building (indirect waste), such as the excessive thickness of plastering. It can be caused by a wide range of reasons: poor design and specification, lack of planning and control, poor qualification of the team work, lack of integration between design and production, etc.

(9) Others: waste of any other nature than the previous ones, such as burglary, vandalism, inclement weather, and accidents. The controllable wastes into three different activities, which associate with flows, conversions, and management activities: (1) Controllable causes associated with flows: (a) Resources: (i) Materials: lack of materials at the work place; materials are not well distributed; inadequate transportation means; (ii) Equipment: non-availability; inefficient utilization; inadequate equipment for work needs; and (iii) Labor: personal attitudes of workers; rebellion of workers; and (b) Information: (i) Lack of information; (ii) Poor information quality; and (iii) Timing of delivery is inadequate; (2) Controllable causes associated with conversions: (a) Method: (i) Deficient design of work crews; (ii) Inadequate procedures; and (iii) Inadequate support to work activities; (b) Planning (i) Lack of work space; (ii) Too much people working in reduced space; and (iii) Poor work conditions; and (c) Quality: (i) Poor execution of work; and (ii) Damages to work already finished; and (3) Controllable causes associated with management activities: (a) Decision making: (i) Poor allocation of work to labor; and (ii) Poor distribution of personnel; and (b) Ineffective supervision/control: Poor or lack of supervision. Modeling, evaluation of wastes, and performance in construction projects have been a challenge for the construction industry for decades. Several models and procedures have been proposed for the evaluation of project performance at site and project level. Some of these models focus on prediction of project performance while others focus on measuring. Traditional models offer only a limited set of measures as most of them limit their analysis to a number of measures such as cost, schedule, or productivity (usually labor productivity). The shortcomings of the traditional control systems and models are unable or not appropriate to measure those new performance elements but some of the concepts developed in previous researches can be utilized in modeling new performance elements for construction required for continued improvement. It is worthwhile to point out some opinions of different researchers and authors related to the extent of performance elements in the aspects of construction process. Researches have characterized performance in seven criteria or elements on which management should focus its efforts on as: (1) Effectiveness: A measure of accomplishment of things; (2) Efficiency: A measure of utilization of resources. It can be represented as a ratio of resource expected to be consumed divided by the resources actually consumed; (3) Quality: A measure of conformance with specifications; (4) Productivity: Theoretically, this is defined as a ratio between output and input, and it is primary measured in terms of cost. In the context of the construction industry, the output is the structure or facility that is built or some components of It. The major input into construction process includes work force, materials, equipment, management, energy, and capital; (5) Quality of work life: A measure of employee's affective response to working and living in organizational systems. Often, the management focus is on insuring that employees are satisfied, safe, and secure and so forth; (6) Innovation: This is the creative adaptation process of product, service, process, or structure in response to internal; as well as external; pressures, demands, and changes, needs and so forth; and (7) Profitability: A measure or a set of measures of relationships between financial resources and uses for those financial resources.

VI. CONCLUSION

This research seeks to confirm the following objectives: (1) Determine the implementation of lean ideal; (2) Identify the source of wastes classified under lean construction industry; (3) Examine general perceptions of the construction industry with the lean construction principles of practices; (4) Study reduction and elimination of wastes as classified under development of Last Planner System as a technique of lean construction implementation and to evaluate the effectiveness of implementing last planner to increase plan reliability; (5) Examine the relationship between lean construction and performance improvement programs in construction organizations; and (6) Analyze the characteristics of successful performance improvement programs, and develop a model that identifies three critical elements: (a) Time spent on improvement, (b) Improvement skills and mechanisms, and (c) Improvement perspective and goals. The authors identify different ways to structure improvement program: outcome focused (such as Critical Success Factors) and process-focused (such as Lean Construction). The paper discusses the implications of the different perspectives and argues that they lead to different improvement approaches each reflecting different paradigms for the nature of the change. The authors propose that result-focused improvement programs may be a barrier to the adoption of Lean Construction. The paper proposed a dynamic model of performance improvement process. The model examined the factors affecting the process and their interactions. The paper proposed that: (1) Direction of the improvement effort is strongly influenced by the structure and goals; and (2) Result-focused programs have limited ability to address complex systemic problems. One question for future research is what drives a contractor to establish a result focused or a process-focused program. It appears that specialty contractors are more familiar with the process-perspective because of their familiarity with productivity improvement studies (which is a process analysis of a relatively simple problem). On the other hand, general contractors are more likely to emphasize overall project results. Future research also needs to (1) Develop and validate a more complete model of performance improvement; (2) Further examine the behavior of improvement process over time; and (c) Use the model as a starting point for system redesign by adding loops and breaking links.

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