Value Stream Mapping To Improve Construction Processes: A Review Paper

Arun K Biju [1], Life John [2], Jeevan Jacob[3]
Dept of Civil Engineering
[2, 3]Assistant professor, Dept of Civil Engineering
[1, 2] Toc H Institute of Science and Technology, Ernakulam
[3]Mar Athanasius College of Engineering, Kothamanglam, Eranakulam

Abstract- *In the manufacturing industry, remarkable improvements in productivity are observed which encouraged the emergence of lean thinking into the construction industry. Poor management, output variability, labor intense work, interior work conditions and insufficient quality are the potential problems in the construction industry which lead to implementing lean techniques. Value stream mapping (VSM) represents the main principles of Lean Management, which helps in directly observing the flow of information and materials as they now occur, summarizing them visually, and then envisioning a future state with much better performance. This paper reviewed various papers that related to Value Stream Mapping (VSM) in construction and production industry. The effects of VSM in improving various construction processes and recommendations for future research are the outcomes of this review paper. This review approach on VSM is used to discover and Reduce/Eliminate wastes in the organization and improving construction process.*

Keywords- Lean thinking, Productivity in Construction, Value Stream Mapping (VSM), Waste reduction.

I. INTRODUCTION

Lean Construction is an approach for handling a construction project with maximum value and minimum waste. This can be achieved by developing a value stream that eliminates waiting time and ensures a level schedule in an organization with the help of a tool called Value-Stream Mapping (VSM). VSM documents graphically every stage concerned by the material and information flow starting from the reception of an order and ending with the delivery to the end customer. It is also defined as a pen and pencil tool that uses special flowcharts and symbols to represent the production process and used for the analysis of repetitive processes.

Building sector of the construction industry is unique since the production volume is high and the flow is controllable with a large amount of inventory involved within processes. Seven wastes that are generated out of various processes are overproduction, waiting, over processing, inventory, motion, defects, and transportation. Waste generation can be prevented by effectively managing the flow of information, materials, and resources. This can be achieved by training the site management to identify non-value adding activities, which are generally termed as waste, and eliminating them. The improvements made possible with the help of certain tools that will help in the implementation of the lean concepts and theories for the elimination of wastes that are identified. Among the various tools for implementation that are available, Value Stream Mapping permits a systematic view of the process, identify the process flow and pull the waste according to lean principles. A value stream map has two elements namely the Current State Map and Future State Maps. The current state map represents the current status of the process whereas a future state map is prepared by analyzing and identifying wastes from the current state map and eliminating them using lean principles. The accuracy of the future state map with improvements depends on how precisely the current state map is developed and analyzed. Thus, it is a challenging task by the researchers to judiciously gather information and interlink the problems with the existing practices. The future state map must aim at providing a continuous workflow where the movement of processes, information, and resources are undisturbed and controlled along the end to end construction processes and consider a better and more efficient way to rearrange the process. This review is concerned with the need for spreading and applying the Lean Construction concepts and principles that helps to learn, discover, and Reduce/Eliminate wastes in the organization and improving construction process.

II. LITERATURE REVIEW

Iris D. Tommelein et.al (2005) had done a research on value stream mapping for make-to-order products in a job shop environment. This paper intends to highlight some peculiarities of job shops and value streams of sheet metal fittings that need to be addressed in VSMs. Also, this paper intends to raise the construction industry's awareness for the need to define and systematically evaluate reference indicators, e.g., takt time, batch and buffer sizes, to support

managerial decisions. The discussion was based on the work of mechanical contractor's fabrication shops, but it can be extended to other supplier's fabrication shops with small adaptations. The case study to illustrate the use of VSM for an HVAC sheet metal shop was developed based on real data collected from a time study in an HVAC sheet metal shop and interviews with people in different sheet metal shops. In spite of the effort to quantify outputs of each process, inventories, batch and buffer sizes for different processes and tasks, these numbers remain largely unknown. This was its part because companies do not keep track of this information in a systematic fashion. The release of production orders and withdrawal of finished goods from the system is erratic even for fittings in the same family. This reveals part of the complexity of the system studied.

Lap-Chi Wong et.al (2006) had done a research on The research proposes an application framework for (1) guiding the development of process mapping models and simulation models; and (2) further assessing the cost-effectiveness of on-site waste sorting efforts under practical site constraints such as labor resource availability, time control on refuse chute usage, and limited working area space in a building site. The connection has been established between the mapping and simulation techniques in the context of modeling waste handling processes in construction sites, such that the process flowchart resulting from the mapping technique can serve as convenient model input to facilitate the creation of a "dynamic" operations simulation model. A case study of the on-site waste sorting method with one refuse chute for waste classification is presented to demonstrate the complete application framework spanning (1) process mapping; (2) mapping-to-simulation model conversion; and (3) method optimization based on valid simulations. The problem statement for the case study was first given in the following section. The case study for waste handling is based on experiences and conditions on a typical building site in Hong Kong. The limited space in the congested working area imposes available space as a major constraint in the design of the waste management option, which aims at attaining both productivity and safety. Although the case study is based on experiences and conditions on a typical building site in Hong Kong, it describes waste-handling processes in building sites in general, and hence, can be readily adapted to reflect local practices in other places. The proposed application framework, which is based on a straightforward process mapping technique and a simplified discrete-event simulation approach, holds the potential of becoming a generic methodology that can assist practitioners in improving waste management practices in construction.

Mohamed Al-Hussein et.al (2009) had done a research on Development of Lean Model for House Construction Using Value Stream Mapping. The model had four main features: synchronized first-in, first-out lane-based flow, production leveling at pacemaker, work restructuring, and improved operational reliability. A simulation template was built to verify the model and to assist in the development of interim implementation models. This paper presents data collection and value stream selection, current practice analysis, and specific changes proposed for the lean production model. In the research, a seven-step methodology was adopted: 1 data collection and value stream selection; 2 current-state mapping; 3 existing practice analysis and lean metrics development; 4 formulation of lean production model; 5 laboratory testing of the model using simulation; 6 kaizen continuous improvement plan development; and 7 implementations of kaizen plans and results evaluation. This paper focuses exclusively on the first four steps, especially current state mapping and formulation of the lean production model; simulation and the lean implementation are briefed to provide integrality. This research has focused on creating a stable production flow rather than eliminating individual waste. VSM, a powerful lean planning tool, was used to analyze the construction process and restructure the production system. However, compared to manufacturing, the home building industry poses some significant particularities, making the direct application of VSM impossible. This paper has explicated the major limitations of traditional VSM and proposed a practical approach to utilizing VSM in a construction setting.

Mansooreh Moghadam et.al (2012) had done a research on Integrated BIM/Lean Base Production Line Schedule Model for Modular Construction Manufacturing. This research proposes an integrated model that applies both BIM and lean on a modular construction manufacturing (MCM) process and gains the benefits of both concepts. A computer tool for drafting the modular construction process called MCMPro was expanded to generate the building components' schedule. The Value Stream Map (VSM) of the factory were generated based on the components' schedule through a proposed Integrated Process Improvement (IPI) method using a set of mix lean principles to reduce waste over a broad range of factory activities. A simulation model using Simphony.NET 3.5 was developed to run the generated VSM and produces the results. The proposed methodology validated by a case study, which was a modular building located in Edmonton, AB, and illustrates the effectiveness of the proposed methodology. For this purpose the integrated computer tool for the design and drafting of the modular construction manufacturing (MCM) process, MCMPro, generates sets of shop drawings was expanded to generate building components' schedule and accommodate the proposed methodology requirements Then

the Value Stream Map (VSM) of the factory were developed based on the components' schedule through a proposed method called Integrated Process Improvement (IPI) using lean principles to reduce waste over the factory activities. A simulation model was developed to produce the result of generated VSM. The results proved the effectiveness of the proposed model in reducing waste, time, and resource usage.

Peter Simonsson et.al (2012) had done a research on 'Learning to see' the Effects of Improved Workflow in Civil Engineering Projects. The purpose is to show how VSM can be used by on-site practitioners to see the day-to-day flow of work, to understand the effect of straight-forward improvements to workflow, and to see the effect of applying industrialized working methods. Applicability of VSM to civil engineering is examined through the fixing of reinforcement in two bridge construction projects. A traditional bridge was used to map (current state) and improve (future state) workflow. The potential of modern production methods is then analyzed in a second bridge project (ideal state).The findings help the site management to visualize and to see workflow improves the work performance of the two studied bridges. Addition of easy to understand and calculable metrics for lead time, inventory level and manufacturing costs, emphasize the potential savings of reactive and proactive workflow measures (≈ 80-90 %). The paper considers fixing of reinforcement in two bridge construction projects. Additionally, the so-called future state bridge was not actually constructed, i.e. the savings stated for the future state, even if reasonable, are an approximation. The framework to visualize current, future and ideal workflow provides a framework to extend the VSM methodology to civil engineering projects. To overcome the sub-optimized mindset in civil engineering that repeatedly leads to the same practice, the paper proposes a straightforward and easy to use a framework to visualize and analyze effects of workflow improvements.

Ann Francis et.al (2012) had done a research on Impact of Value Stream Mapping in Indian construction sites on reducing carbon emissions. This paper attempts to validate this notion on Indian construction sites and also attempts to compare the extent of productivity enhancement and emission reduction across a spectrum of construction activities, in order to achieve a better understanding of where 'Lean' principles can be best used for improving sustainability. The paper considered five different construction activities - Piling, Construction of Open Foundations, Slab Concreting, Block work and Fabricating Steel Trusses. The research used Value Stream Mapping (VSM) - a popularly used and standardized 'Lean' technique to map the current execution process for each of these activities and optimize productivity using Lean techniques. Using simulation techniques, here simulated the post-optimization performance of these activities. By comparing CO2 equivalent emissions in the original state and in the optimized state for each activity type, was able to assess the role of Lean practices in promoting sustainable construction. Our results indicate that while Lean construction can lead to Green construction across all the activities that we considered, the extent of emission reductions was highest in the construction of open foundations followed by block work and piling. Only negligible improvements were visible in concreting and structural steel fabrication. The findings are of relevance to policymakers, practitioners, and academics as they seek to make the construction industry more sustainable.

Johan Vessby et.al (2012) had done a research on Identification of potential improvement areas in industrial housing: A case study of waste in the construction industry. The purpose of this paper was to categorize waste in the construction industry for a specific building system (using wood as the load-bearing elements). This case study mainly focused on the following three parts: 1) current state maps of the supply chain; 2) identification of waste appearing at the construction site, and 3) a time study of the installation process. This paper proposed that the waste in the construction supply chain for the current case can be categorized as follows: Defects and Controls, Logistics, Utilization of Resources, Health and Safety, and System and Structure. The current paper was based on a single case study; and hence, its results need to be replicated in further studies. This study contributed previous knowledge with regards to lean construction and waste (as it specifies the waste concept with regard to the construction industry). This paper provides a categorization of waste in the construction industry in which the categories are inherent from the same source. Hence, elimination of the waste is facilitated by identifying an overall solution for each category rather than for individual types of waste.

Adam Brandon et.al (2013) had done a research on Analysis of the Work Flow in a Complex Project. The paper presents the findings of a study conducted at a large 360-bed and730,000+ square feet hospital in Southern California. The main purpose of the study was to investigate the workflow of trades working on the project site and to identify problems that prevent a continuous flow of work of drywall, electrical, and mechanical trades working in different rooms. Data was collected through different methods including direct observation of the work and trade meetings, document analysis, value stream mapping, and interviews. The paper focuses on a specific area of the project related to building repetitive units (rooms and bathrooms). A large portion of the lead time to complete the units was related to waiting/idle times resulting from problems in the information flow and especially how people make commitments to execute these

tasks. This paper presented a case in which a small batch of bathrooms in a large complex project was left behind due to numerous issues (e.g., low priority, lack of information to proceed, numerous cycles of inspections). Consequently, a number of non-value adding activities took place, the lead-time to complete the units was stretched, and the units could not be completed and handed off to the next trades. This paper presented a single case in which these problems happened and illustrated how much waste ends up hidden in a construction project. The authors did not study in detail the value-adding activities (e.g., framing, taping) but would speculate that these could also be studied and the times to perform them can certainly be decreased.

Giorgio Locatelli et al. (2013) had done a research on Improving Projects Performance with Lean Construction: State of The Art, Applicability, And Impacts. The research was based on data from the literature and empirical. 7 new Case Studies was built with primary data, 12 Case Studies on CLIP (Construction Lean Improvement Programme) projects, 4 semi-structured Interviews with Firms adopting LC and several interviews (face to face and email) with LC experts. The research was based on literature review, case study analysis and interviews with top- experts. Lean thinking applied to construction can be summarized in: waste elimination; Improving reliability; Creating continuous flow in a pull system; Meet the customer's need; Involvement of workers at every level; Involvement of supplier and client in the project process; Built-in quality; Continuous improvement; Knowledge sharing. The most common benefits of LC are a shorter delivery time and a higher project performance because The Productivity of the workforce increases. There are a better coordination and communication with suppliers. There was a minimization of re-working following the lean principles "Do the right thing at the beginning". There is a minimization of no value- added activities focusing on the real customer's needs.

Remon Fayek Aziz et.al (2013) had done a research on Applying lean thinking in construction and performance improvement. This research discussed the principles, methods, and implementation phases of lean construction showing the waste in construction and how it could be minimized. The Last Planner System technique, which was an important in applying the lean construction concepts and methodologies and is more prevalent, proved that it could enhance the construction management practices in various aspects. Also, it was intended to develop a methodology for process evaluation and define areas for improvement based on lean approach principles. 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 was used to evaluate the effectiveness of implementing the last planner to increase plan reliability; (5) Examined 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.

Carlos Antonio Samaniego Gallardo et.al (2013) had done a research on Productivity Gains in a Line Flow Precast Concrete Process after a Basic Stability Effort. This study took place at a company that had previously implemented lean measures, such as value stream mapping (VSM), workplace organization (5S Method), pull systems, and total productive maintenance (TPM). This earlier initiative provided productivity gains, although in a variable and unstrained way. The research approach could devise a simple stability process with a focus on method and manpower. After a series of improvement cycles, the production process achieved almost complete stability and obtained an additional productivity gain of 24%. These results suggest that neglecting stability issues in lean implementations means wasting part of the potential gains, in addition to risking the loss of previously obtained gains, even in environments apparently optimized for line flow. This research was motivated by questions that arose during the observation of a precast concrete tile production line, which was originally conceived as line flow. In this case, the initial implementation of these lean tools, achieved before this action research, showed that these gains are also obtained in line flow, increasing productivity by 25%.

Abhigna E Desai et.al (2014) had done a research on Value Stream Mapping as a Lean Construction Tool – a Case Study. Value stream mapping (VSM) was used to identify value-adding activities and those considered wasteful of materials and the flow of information and people. The purpose of studying this tool was to understand how Value stream mapping (VSM) is helpful in lean implementation and developed a roadmap to tackle improvement areas to bridge the gap between the existing state and the proposed state of different construction activities. For mapping, the current state map, the information for different RCC activities for slab preparation was collected from the contractor, site engineer, site supervisors, and workers. The data like, types of activities, its quantity for a typical slab, no. of days and resources required for RCC activities are gathered. Using this

methodology, the considerable results were achieved. The slab cycle time for a typical slab, Service floor slab was reduced to 13 days from 15 days. The additional cost required for applying innovations should be considered. For this case study, the off-site column fixing saves 2 days in the cycle time but, for erecting the cage of column a tower crane is required. The rental of tower crane should be considered. It should not exceed the amount saved for two days. Applied Innovation has to get savings in comparison with the current practice on construction site. It should be considered that the readymade steel is 8 to 10% costlier than the normal steel. And the scrap value of waste cut pieces of steel should also be considered before taking decisions.

Vicente Gonzalez et.al (2014) had done a case study on Improving Environmental and Production Performance in Construction Projects Using Value-Stream Mapping. This study provided with a detailed experience of the VSM application in construction, confirming its ability to detect the sources of environmental and production waste, quantify them, and suggest reduction strategies. Here presented the development of a well-established implementation process of the VSM. This case study reinforces the effectiveness and proposed a green-lean approach for improving the sustainable performance of construction projects. It can help to optimize the use of resources and reduce costs, improve quality standards, and minimize the environmental impacts generated by the construction projects. This research methodology was based on the analysis of a medical center project in Chile as a case study. The scope of the work was included with the fundamental construction activities that were part of the structural concrete work. The VSM implementation included data collection and processing, measurement of indicators, elaboration of the current state maps, diagnosis of the current state, and elaboration of the future state maps, as well as the recommendations for achieving the future state of the value stream. Finally, expert opinion was used to validate the current state value stream maps and to check the feasibility of the future state maps and their implementation plans.

Dorota Stadnicka et.al (2017) had done a research on Value stream and system dynamics analysis – an automotive case study. The present case study a production line where automotive door seals are manufactured was analyzed. First, an analysis of the use of value stream mapping was undertaken in order to identify processes and a material flow. The current state and future state maps were developed. Then, these maps were used to prepare the model of the production system, of which dynamics have been analyzed with the use of Vensim software. As the results, the dynamics of inventory levels along with the manufacturing system were obtained. The present case study was on the basis of the data gathered from a mean level where automotive door seals are manufactured, value stream mapping and value stream analysis have been performed. The current state map has been developed and then analyzed. problems have been identified. Then, on the basis of analyses results the future state map was proposed. the future state map presents the possibility for improvements. in current state map real inventory levels have been presented and in future state map, maximum inventory levels have been established. Next, on the basis of the current state map, a system dynamics model in Vensim has been developed and inventories variations in the range of time have been analyzed with the use of this model. As the results, we have obtained the dynamics of inventory levels along with the manufacturing system.

III. DISCUSSION

Lean is a management philosophy focuses on the reduction of the seven wastes in manufactured products-overproduction, waiting time, transportation, processing, inventory, motion and scrap. By eliminating waste, quality is improved, and production time and costs are reduced. Value stream mapping (VSM) is one of the main tools of Lean Management which enables the user to map a process with respect to the value added activities. VSM helps to identify all types of waste in the value stream and target specific areas for improvement. It helps to see the big picture and improve the whole flow. The improved value stream maps can be used as guidelines for future studies. In almost all literatures, here shows the application of VSM on Project as a case study and VSM is used to reduce time by combining and eliminating different process which is non-value added. There is a minimal reference to monitoring the productivity laborers involved in the processes and the generation of a framework for the application of VSM in a building project in the construction stage.

Khaja Layeequddin et.al (2017) had done a research on Lean Construction – Application of Value Stream Mapping on Infra Structure Project. This study demonstrated value stream mapping can also be applied to the movement and processing of information in Infrastructure projects. From the current construction practices, it takes about 40 days to cast a single slab. The value stream map shows that 7 days of this time consists of non-value added activity such as backlogs and waiting. Using Lean tools both value-added and non-value added activities on the value stream map can be identified. The future state map shows how the process might be improved after changes are made to the process. The challenges in the organization was to organizing the information in the VSM to remove or reduce the non-value added steps. The case study looked upon the applicability of

Value stream mapping in the casting of slab activity where work is carried out in a repetitive manner. Regarding the elimination of waste leading to cost efficiency value, stream mapping seems to have at least the possibility to identify waste for administrative purposes. Value stream map is a mapping tools only give as much information as the data input into it. By establishing a batching plant at the site there would have been the cost reduction in the ready-mix concrete of a margin about 15-20% to the client. Proper planning from the contractor side helps in making the materials readily available at the site thereby not delaying the activities as per plan. By increasing the duration of activities there had been an increase of about 28 percent in the total wage payment given to the crew. The model generated dependent on quantitative information – transforming input to output. For projects which are in starting stages, this tool might not be that useful because of unavailability of complete information.

IV. CONCLUSION

The literature review targets to support the application of value stream mapping tools in the construction industry. This supports to identify wastes embedded in the working process by visualizing the non-visible information flow. It helps in improving construction process and in understanding a powerful lean tool. This powerful tool not only highlights process inefficiencies and transactional and communication mismatches, but also guides the organization in improving these areas. This literature review provides a current study of value stream mapping and its current application in construction. Successful implementation of VSM will also help to show the positive change that can be developed through the use of this Lean tool. Future research would explore the application of value stream mapping in construction information flow in a more complicated projects in macro level.

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