Implementing Value Stream Mapping Tool in Construction

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Abstract: ***The purpose of this study is to verify the applicability of the Value Stream Mapping confirming its ability to spot the root source of wastes, reduce the overall lead time of the project, improve the workflow of activities, improve quality of work, and create customer satisfaction as per value defined for the construction project. For research study, civil work of the underground floor and ground floor was taken into consideration, which is further bifurcated into five stages having a total of forty-five activities. Data is collected from site and fed in the Current Map from which, along with the information and material flow, the root cause of wastes from different activities are spotted and the solution of the same activates is illustrated in the Future Map using proper lean symbols, which has reduced wastes, better flow and improved lead time.***
For this paper, one activity namely 'Ground Floor Column Concrete' is selected to illustrate the current and future map. It is found that the lead time of this activity is reduced which will bring various cost benefits and will be useful for the researchers and practitioners in understanding the framework of lean implementation in civil engineering projects, as obtained results encourage its transferability to similar projects.
Index Terms- Lean Construction, Value Stream Mapping, Current State Map, Future State Map, Waste Management.

I. INTRODUCTION

Lean has an effective tool created by Toyota, namely Value Stream Mapping (VSM) which makes a flow map of various activities of the project and makes it easier to spot the waste from the project activities. The aim of VSM is to recognize the wastes and remove/reduce them from the value streams, thus increasing the effectiveness of the selected value stream. Waste elimination is projected to boost the productivity by applying VSM principles which in turn make waste problems easier to spot.

Lean tool optimizes the planning, designing, labor, material, resource management and implementation of different activities. New technologies increase productivity, but various construction wastes like delays, rework, and inventories are still big challenges which affect the project by increasing efforts, time and cost of the project.

VSM illustrates a graphical representation which includes the material flow of different activities and their information from the start to the delivery of the project, using standard symbols. After preparation of the map, it is used to find and eliminate the seven lean wastes which help in making the future map, illustrating the activities with a proper solution.

VSM focuses on recognition and minimizing/removing the wastes, decrease the lead time of the project, boost the productivity, by mapping the whole project scenario using a current map and after analyzing it, mapping the future state of the map with improvements. Also, this study emphasizes on understanding the implementation and application of the VSM tool in the construction industry to demonstrate the way in which VSM can be used on construction site by practitioners to observe the routine flows of work.

II. TYPES OF WASTE

Lean philosophy targets seven types of waste, which are described below:

1) Transportation waste occurs whenever there is an unnecessary flow of information, labor, and machinery as they are not needed for that particular activity.
2) Inventory waste occurs whenever there are extra materials stored which is not required for activity immediately, which also blocks capital, require storage space, and often ruins when not used.
3) Motion waste happens due to unessential movements including the excess distance between labors, equipment or material.
4) Waiting waste occurs when the preceding activity gets delayed which makes the succeeding activity to wait. Also, this waste occurs when there is improper management of material, equipment or labor, which further leads the activity to wait.
5) Overproduction waste generates when any activity is completed before it is scheduled, or when a succeeding activity cannot be initiated. Also using more material than required creates this waste.
6) Over-Processing occurs during the execution of the activities which according to the client do not add value. This waste generally occurs during highlighting of different wastes.
7) Defect waste occurs whenever any activity absorbs extra time, effort, or money, if it is not done correctly for the first time.

III. VSM METHODOLOGY

A value stream is a sequence of different activities essential to take a project from initial state to the completed state in which formation of mapping is started with the delivery of resources and ends with handing-over the project. In VSM, standard symbols are used to show the starting point and end points on the left and right side of the map. Data are observed and collected from the site which includes various factors like cycle time, the stock kept, number of labor for different activities, material received from supplier etc. After this information is collected, details are added on the map under the data box of the activity, above which the name of activity is mentioned. After this step, the flowing information within various activities should be mapped which includes the inventory, type of flow, hierarchy etc. Below this, the timeline is shown for each activity which reveals the actual time activity took in execution.

The aim of current map is to disclose the actual map of the activities and the way they got executed on site which let the practitioners spot the cause of waste from its root. These wastes are observed only if the current map is fed with precise and correct details. After mapping the

current state, the assessment of different activities is initiated to remove the seven types of waste, namely; transportation, inventory, motion, waiting, overproduction, over-processing, and defects. Then each activity is closely monitored to find the waste it is generating and the solution to remove or reduce that waste. After this step, a future map is mapped which illustrates the modification and enhancement of the activities thereby generating more value as compared to the current map. The future map also proposes the implementation to achieve more value and reduce waste.

Present Research Work

The present study is carried out at an under-construction building. The mapping in this paper is shown for one activity, and in the same manner, can be done for all different activities. The main objective is to reduce the waste, improve flow, and reduce lead time, which will decrease the cost and execution time of the project.

The main steps of mapping are-

1. Firstly the symbols used in mapping are shown for customer and supplier.
2. Data is observed from the site and is processed in the required format. Such data includes lead time, volume of work, cycle time, work output per day, number of labors in different category etc. After data processing, information is filled in the data box of the activity and a timeline is drawn below the box mentioning the days required for execution of each activity.
3. The quantity of material is found by the known volume of work.
4. Flow of material is illustrated using the arrow symbol; also the hierarchy shows that the site engineer will inform administrative office from where the supplier will be informed about the required quantity of material which will be delivered by him.
5. Between activities, the material stock in the form of cost is shown which shows clearly the capital involved due to inventory.
6. After the current map is made, it is analyzed based on lean principles and the root causes of wastes are spotted and in the future map, solution to remove these wastes are illustrated using proper symbols.
7. Improvements gained in future state map are compared with the current state map to emphasize the wastes reduced or removed in the form of time and money.

Data Collection

In construction projects, it is commonly seen that several crews work simultaneously on different activities; therefore, data collection at the site cannot be done in a single day by personal observations as is the case in manufacturing.

In this paper, we focused only on one activity and the application of VSM is shown for the same activity. Data must be cautiously collected for current state map, as the correct mapping of the future state map is dependent on precise mapping of current state. Based on our research work, nine essential measurements were calculated:

1. Cycle time
2. Changeover time
3. Volume of work
4. Work per day for every activity
5. Days required to complete an activity based on calculations
6. Days actually took at site to complete the activity
7. Percentage work per day
8. Number of workers based on different category
9. Lead time of whole project

The below table shows the definitions of key VSM measurements used in the research.

Table 3.1: VSM Key Element

Key concepts	Symbol	Definitions
Cycle Time	CT	The time duration that a team requires to complete unit of given work.
Changeover time	CO	In a repetitive task, it is the time required by a team between completing a part of an activity and starting work on same part of that activity again, which takes into account the mobilization and demobilization as well.
Lead Time	LT	It is the time taken from the start of work, including all value streams, until the finish of work.

Current State Map

A value stream map clearly illustrates actual scenario of site rather than watching the project on computer based on predictions. Mapping starts with the selection of a range of activates to be considered, but in construction, waste can be generated from every activity so it is better to select all civil work activities at floor rather than selecting some activities. But for this paper, we are considering only one activity. At the site, the labor team workings on activities are observed and data from different activities like cycle time, material stored, excess unnecessary movements push flow etc, are observed. It should be kept in mind that it takes weeks to collect the actual data from site, as activities take place step by step.

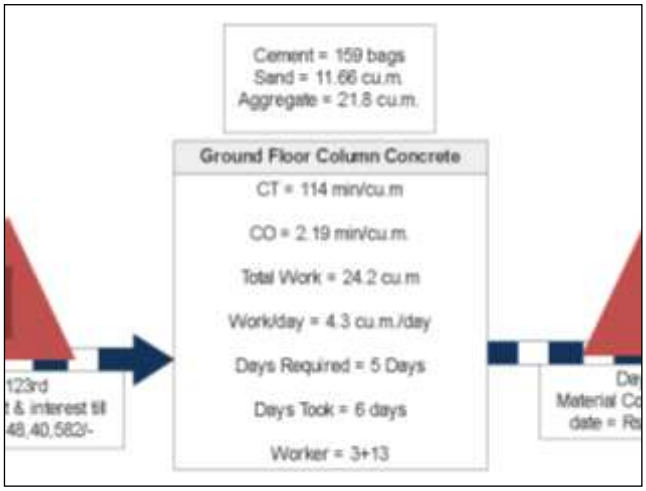

Fig 3.1: Current State Map of Activity

Fig 3.2: Casting of Column

The second step is to connect the flow of information and material of various activities. After completing this part, the timeline underneath the activity box is drawn which specify the days each activity took in execution, and inventory in terms of cost is shown between activities using a triangular symbol.

Analysis of Current State Map

After completion of the current state map, it is analyzed to find the root cause from where the waste is being generated. There are seven lean wastes that can facilitate the improvement of the current map which are illustrated in the future map. Also, the flow between each activity is sought to pull instead of push, which overall accounts in achieving reduced lead time and reduces the total time & cost of the project while improving the quality of work.

Fig 3.3: Excess storage of Steel

Fig 3.4: Excess storage of Sand and Aggregate

Fig 3.5: Bulldozer bringing sand at work site

The activity considered has excess inventory as a prime waste, and proper inventory control solution is recommended in the future state map which is based on Just In Time model and Kanban system. Another issue noted in this activity is excess material is stored far away from the ongoing activity site and was bought to the site using dozer which created motion waste.

Every activity of the project should be closely checked regarding what waste that activity is generating and how it can be removed or reduced, and the mapping of current state map makes it easy to identify them. All wastes spotted should be removed or reduced and the solution should be shown in the future state map.

Future State Map

The map of the future state is drawn based on the map of the current state for every activity and the improved activities are highlighted with the symbol of solution applied to achieve those improvements. Also, the flow of information or material, if improved, is shown in the future map. A system based on a FIFO lane is recommended in future map as compared to the push system in the current map. It is significant to make clear that the unit flowing throughout the activity path is not represented as square or linear meter since this would not be practical. In its place, there would be whole activity flowing through FIFO lane.

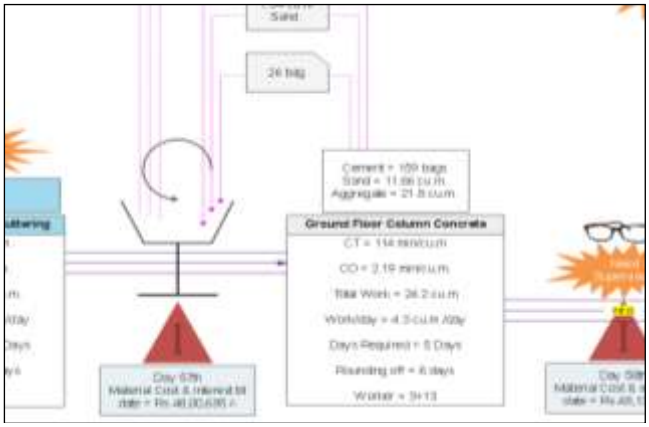

Fig 3.6: Future State Map of Activity

Theoretically, the FIFO concept states that whenever an activity goes into execution stage, it must be the first one to get executed. All push flows have been replaced by FIFO lanes if not pull in any case and Kanban system is set to receive different materials as and when required since the supplier delivers all material labeled according to batch Kanban card only.

But it should be kept in mind that lean is a 'Kaizen' process, which means there are possibilities of continuous improvements. The future map can be further used as a current map in later studies to further analyze the waste and can be improved thereafter.

IV. DETAILS OF ACTIVITY

Details of different activities is firstly observed from site and based on observed activities, some data been calculated in the required format. Also, the number of different categories of workers is observed and mentioned below.

1) Observed Data:
- Time available/day = 510 min/day
- Cycle time of mixer = 9.04 min/cu.m
- Cycle time of transporting = 32.8 min/cu.m.
- Cycle time of placing = 114.5 min/ cu.m.
- Changeover time of placing = 2.19 min/cu.m.
- Wet quantity of Cement = 100 bags
- Wet quantity of Sand = 6.93 cu.m.
- Wet quantity of Aggregate = 13.87 cu.m.
- Dry quantity of Cement = 154 bags
- Dry quantity of Sand = 10.68 cu.m.
- Dry quantity of Aggregate = 21.36 cu.m.

2) Calculated Data:
- Total volume of work = 24.28 cu.m.
- Cycle time as a whole Activity = 114.5 min/cu.m.
- Changeover time as a whole Activity = 2.19 min/cu.m.
- Work/day = 4.40 cu.m./day
- Total days required for activity = 5.53 days
- Percentage work per day of activity = 18.08 %/day

3) Workforce:
- Workers for activity/day = 3 Mason + 13 Helper

V. RESULTS AND DISCUSSIONS

When assessment of current map and future map is done, it is found that the activity taken in account could have been finished in 5 days, whereas in current map it took 6 days, thereby creating pure waste of 1 day and increasing the lead time for the activity by 20%. Further, the reduction in waste from all the activities of the project can significantly improve the lead time and reduce cost of the project.

In current map, a variety of wastes were recognized, as tabulated below, and later reduced or removed by implementing appropriate solution illustrated in the future map. This method helps in reducing the lead time & project cost, improving quality & workflow of the project and this paper is expected to help the practitioners in their future researches.

Table 5.1: Wastes observed

Wastes Observed	**Name of Activity**
	Ground Floor Column Concrete
Motion	It is recommended to store material close to the mixer machine to reduce motion waste, as it takes unnecessary time and efforts to bring the material which is brought using the bucket of the dozer.
Waiting	Placing cycle time is too much so it is recommended to increase the number of mason for placing to increase the productivity as placing time is making whole activity wait.
Over-Production	It is observed that the mixer is mixing material early as compared to the utilization rate of material, also early mixing causes early pouring in chute, in which mixed material sometimes, exceeds the chute capacity and fall on ground and is wasted.
Defects	Appropriate compaction is not done, as a result, after deshuttering of the column; honeycomb defect is observed which is acceptable, but consumed extra time, efforts and material.

VI. REFERENCES

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