



**INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH  
TECHNOLOGY**

**VALUE STREAM MAPPING: CASE STUDY ON RESIDENTIAL CONSTRUCTION  
SECTOR**

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**ABSTRACT**

Since 1993 the ideas of Lean Production have been introduced in construction, creating Lean Construction. Although studies have demonstrated good results from the introduction of Lean Production in construction, these efforts have turned into a specifically isolated implementation, limiting possibilities of improvement along the value flow.

A tool that has been widely used in manufacture, as a way to initiate a systemic implementation of Lean Production, is called Value Stream Mapping (VSM). Because VSM represents the main principles of Lean Production, makes it possible to identify throughout the value flow the main problems and process wastes, and to consider action for improvement.

Aiming to introduce the ideas of Lean Production in construction in a more systematic way, identifying its main problems and proposing actions for improvement throughout the value flow, this article describes the modifications and application of the VSM in a Brazilian construction company. Modifications of VSM were necessary due to the difference between manufacture and construction. Through its application it was possible to identify problems and to consider some actions for improvement, turning it into a more fluid production, with fewer stops and increasing the planned flow versus the accomplished one.

**KEYWORDS:** current state maps, future state map, lean implementation, waste management.

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**INTRODUCTION**

Lean Construction can be defined as handling a construction project as a temporary production system while delivering the product with maximum value and minimum of waste, This can be achieved by developing a value stream that eliminates waiting time and ensures a level schedule, and to do so organizations have at their disposition a tool called Value-Stream Mapping (VSM). VSM documents graphically every stage concerned by the material and information flows starting from the reception of an order and ending with the delivery to the end customer.

VSM is different than conventional recording techniques, as it captures the information at individual stations about station cycle time, up time or utilization of resources, set-up time or change over time, work in process inventory, man power requirement and the information flow from raw material to finish goods. It covers both value adding as well as non-value-adding activities. It's important to note that value stream mapping is a relatively recent addition to the slate of Lean tools. A value stream is defined as all activities and events (both value-added and non-value added) that a product or service passes through on its way from supplier to customer. In a manufacturing facility these activities include shipping, waiting (in inventory, in a queue to be processed, or even in an oven waiting for adhesives to cure), packaging, inspection, rework, and both manual and automated processing. A VSM includes both the flow of product and information.

**OBJECTIVE OF PROJECT**

1. Study of Lean Construction as a new technique applied for construction industries to increase productivity & minimising waste.
2. Collection of data –in site and outside data for residential building
3. Analysis of collected data by Value Stream Mapping tool.

Preparation of the current state map- Understanding how the project currently operates.

Material and information flows (currently to focus on material flow only).

Draw using icons.

Start with door to door (in-house loop)

4. Preparation of future state map  
There must always be a Future State Map – i.e. continuous improvement at the value stream level

When the Future State Map becomes a reality, a new Future State Map should be drawn.

Don't get hung up trying to make all the details on the Future State Map perfectly correct.

Fine the Future State Map as the implementation progresses.

## METHODOLOGY

The following is a brief description of VSM steps:

1. Preliminary decisions: The product families to be analyzed and the indicators needed are chosen.
2. Data collection on-site: Data are collected by direct observation and interviews. The research period was 2 months and approximately 430 staff hours of field measurement were spent.
3. Data processing: Data collected on-site were processed to calculate the defined indicators.
4. Elaboration of the current state maps: Using the calculated indicators and observations, the current state maps were elaborated.
5. Analysis and diagnosis of the current state: The current state maps were analyzed in order to detect production and environmental waste in the value stream.
6. Elaboration of the future state maps: Using a green-lean approach, the desired future state of the value stream was created.
7. Recommendations for achieving the future state: Recommendations were made to establish an implementation plan to produce future plan.

## DATA COLLECTION & VALUE STREAM COLLECTION

An important role in VSM is to bring the stop watch when walk- in along the actual pathways of material and information flow. High variability in task durations as well as queuing times and complexity in the construction process make it impossible for researchers to collect sufficient data merely through site observations. Instead, an internet-based production tracking system was developed, in which site managers recorded the booking date, confirmed start date, actual start date, and actual finish date of every task in the construction process..Based on the data, four basic measurements were calculated:

1. Cycle time CT
2. Booking time BT;
3. Lead time between tasks LT
4. Percent started on schedule PSS.

Commencement of VSM:

Select a value stream

Decide on the level of mapping.

A value stream is a series of activities required to bring a product or service from raw state through to the customer As a manufacturing plant usually fabricate multiple products each by a unique transforming process ,the product family with the highest production volume is In addition to data collection, two management decisions must be made prior to the generally selected as the target on which to focus improvements.

Level of mapping is another important issue to be considered in defining the value stream .In manufacturing, mapping generally begins at the level of the production process in a single plant, with the activity box indicating a continuous product flow. In other words ,the tasks in the map are divided at the places where the product flow stops and in-process inventory accumulates .In construction, the houses products do not move along a production line but rather workers move from one house product to an- other. Thus, the operations of at radices can be regarded as a continuous flow and would be shown with one activity box on the map.

For data collection we have selected 54 duplex bungalows and Three G + 3 apartments at Warhol, Pune.This is residential project site taken as case study the data collection for G+3 apartment has follows.

Name of Activity	Quantity of Work	Work done per day	Diff. type & no. of Workers	Duration
Line out & Earthwork in excavation.	64.23 m <sup>3</sup>	28.30 m <sup>3</sup>	Belders-5, Mazdoor-4	3
PCC Work.	20.11 m <sup>3</sup>	8.50 m <sup>3</sup> Per person	Mason-1, Mazdoor-2, Bhisti-1	3
Foundation.	44.95 m <sup>3</sup>	1.25 m <sup>3</sup>	Mason-7, Belder	6
Murum filling.	47.5 m <sup>3</sup>	4 m <sup>3</sup>	Belder-3	4
Damp proof course.	24.76 m <sup>2</sup>	35 m <sup>2</sup>	Mason-1	1
Brick work in superstructure	66.59 m <sup>3</sup>	2.83 by 3-Masons, 5-Mazdoor, 1-Bhosti	Mason-5, Belder-3, Coolie-5, Bhisti-2	14
Lintel work.	20.40 m <sup>2</sup>	9.6 m <sup>2</sup>	Belder-4,	3
Concrete work for Lintel.	3.01 m <sup>3</sup>	2.83 m <sup>3</sup>	Belders-2, Mazdoor-3,	1
Cutting & Bending, Centering, Shuttering & Binding steel for	167.27 m <sup>2</sup>	9.6 m <sup>2</sup>	Belder-10, Carpenters-2	6
Concrete work for Slab.	25.9 m <sup>3</sup>	2.83 m <sup>3</sup>	Mason-4, Mazdoor-12, Coolie-20, Bhisti-7	10

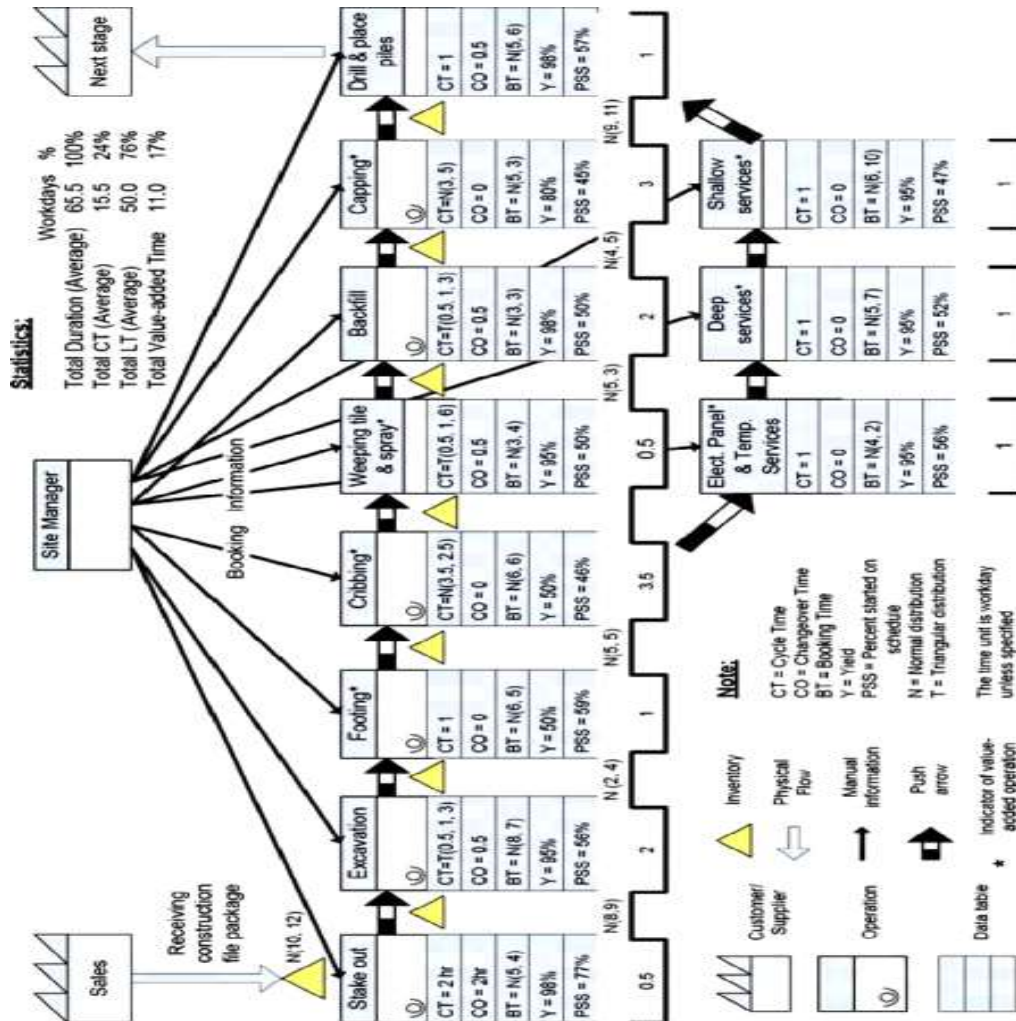
Plumbing.	Lump		Plumber-2	3
Internal plastering & Dado work.	437 m <sup>2</sup>	40 m <sup>2</sup> by Masons-3, Mazdoor-3, Bhisti-1	Masons-10, Belder-15, Bhisti-	8
External plastering.	150.5 m <sup>2</sup>	40 m <sup>2</sup> by Masons-3, Mazdoor-3, Bhisti-1	Masons-5, Belder-8, Bhisti-1	3
Flooring.	143.35 m <sup>2</sup>	40 m <sup>2</sup> by Masons-5, Mazdoor-	Masons-5, Belder	4
Wood work.	2.52 m <sup>3</sup>	0.5 m <sup>3</sup>	Carpenters-2, Beldar	6
White wash.	587.5 m <sup>2</sup>	60 m <sup>2</sup> by Whitewasher-1, Mazdoor-1	White washer-4, Mazdoor-2	5
Coloring.	587.5 m <sup>3</sup>	35 m <sup>2</sup>	Painter-4, Mazdoor-2	7
Electric work.	Lump Sum		Electrician-4	3
Electric work.	Lump Sum		Electrician-4	3
Excavation for compound wall.	19.66 m <sup>3</sup>	28.30 m <sup>3</sup>	Belders-5, Mazdoor-4	1
Compound wall construction	52.50 m <sup>3</sup>	1 m <sup>3</sup> per Mason	Masons-12, Mazdoor-10, Coolie-7, Bhisti-2	5
Painting for compound wall.	350 m <sup>2</sup>	10 m <sup>2</sup>	Painter-5, Mazdoor-3	6
Cleaning.	Lump Sum			1

## MAPPING PROCESS

### Current State Map-

Upon drawing up the current-state map several wastes can be identified immediately. The total duration of Stage 1 was found to be 65.5 workdays, but the total lead time accounted for 50 work days. This means that houses in

construction stand idle about 76% of the time, with no construction activity on site. One apparent cause of long lead time is the high level of variability of the process. The booking times and cycle times in the map are very variable. Six of 1 booking times have a standard deviation in excess of 5 days and cycle times of five tasks must be described using statistical distributions. In the current practice, site managers book the downstream sub trade immediately following confirmation of the start date of the upstream tasks. perspective of the footing contractor, a sudden schedule change means that it must find a new job fitting in that time slot in a very short period of time. Then, overbooking i.e., sub trades accept jobs exceeding their capacity has become common practice. Consequently, a greater number of tasks fail to begin on the scheduled start date and lead time become seven more unpredictable.



**Future State Map**

The focus of future-state mapping is to eliminate the root causes of waste and to link the value stream in a smooth flow. Unlike manufacturing, where the fundamental problem is overproduction caused by “batch and push” the home builders need to sustain a large work force pool and cannot provide stable workflows to trade contractors. In order to reduce the variability of the process the following four measures were taken in the future-state mapping establishing a production flow and synchronizing it to takt time; leveling production at pace market task; restructuring work; and improving operation reliability with work standardization and total quality management

**First-in, First-out Lane-Based Flow and Its Synchronization**

In manufacturing, continuous flow forms the center piece of the lean production system and is regarded as the most effective way of production. Never the less, the production system built on continuous flow can only be used for are

liable process. As the system is fully synchronized, any small delay or break down in one operation will result in halting the entire system. Housing construction is a site-based production as opposed to factory-based manufacturing. Weather and site conditions have a significant impact on the execution of construction activities, so variation in task duration is unavoidable. In addition, the housing construction process is a long process involving more than 60 work "packages" tasks. Connecting all the tasks into a continuous flow would make the system very fragile. Finally, construction work is performed by various trade contractors who have individual interests and are almost exclusively concerned with the efficient execution of their individual tasks. Therefore, keeping an excess capacity buffer to overcome min or flow fluctuation is not practical for home builders.

### **Production Leveling**

In the conventional production management approach, the volume of jobs performed typically occurs unevenly over time.

The causes of this large fluctuation were unpredictability of sales and a pushed production management. Flow fluctuation causes several problems for a synchronized production system:

- There is no sense of takt time and it is difficult to decide the capacity requirement;
- When peaks and valleys frequently appear, filling the agreed kanbans lots consistently becomes a heavy burden; and
- A jangled flow makes the production difficult to monitor—"Is the situation normal or not?"

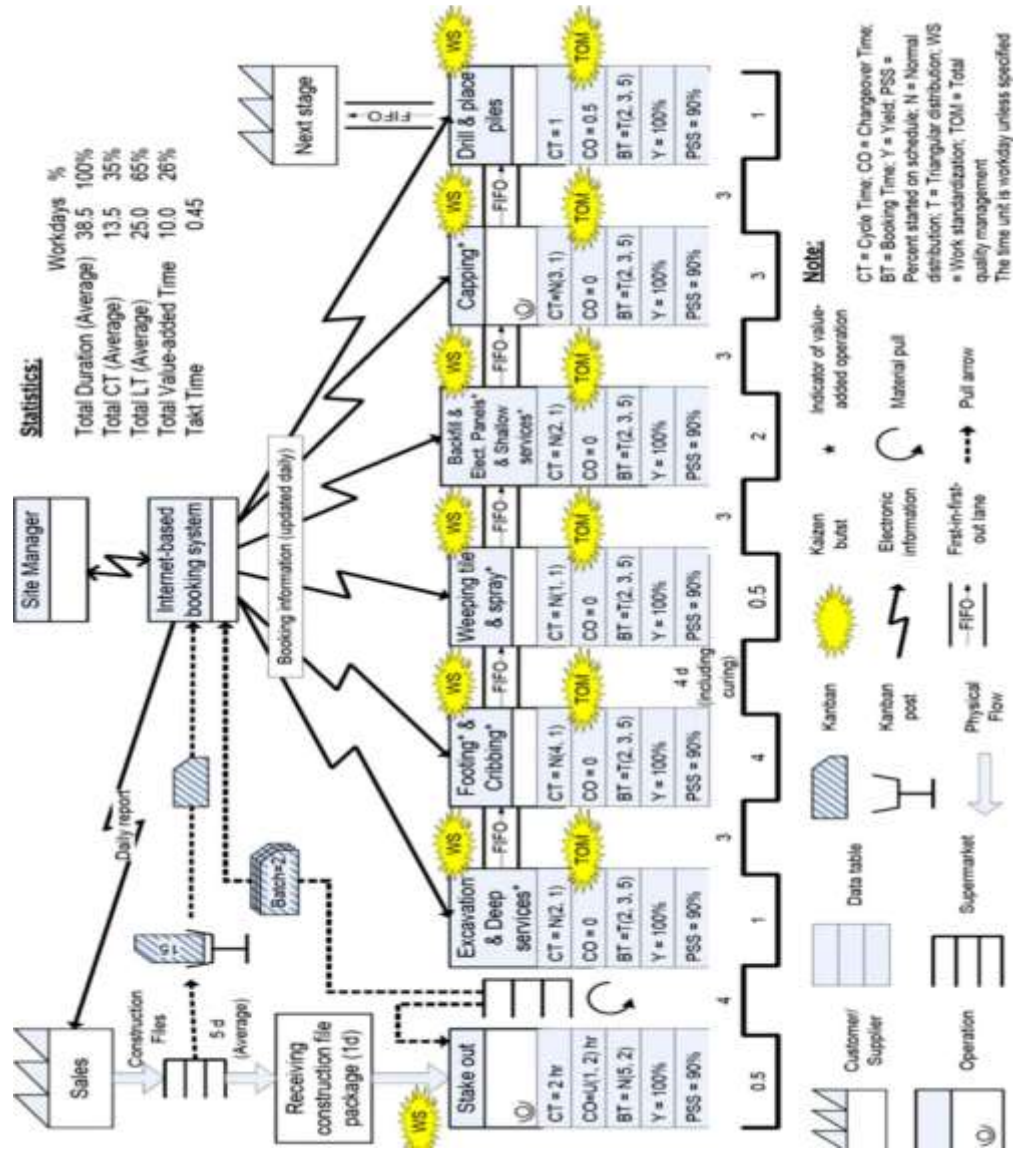
In order to avoid these problems, the production control must lower the peaks and raise the valleys in work load as much as possible so that the flow surface is smooth. This practice is referred to as production leveling or "even production flow."

### **Work Restructuring**

It is apparent that the total lead time can be effectively abated by reducing the number of handovers. In an extreme case, if the entire value stream could be completed by a single crew, the house would pass directly from one task to then extend a continuous flow, without any lead time in between. The factor that prevents the same crew working continuously in a house throughout the value stream is that different tasks required skills and equipment. Although multi skilling and the use of cross-functional teams were shown to be effective in reducing variability and thus improving flow the reality is that the vast majority of trade contractors are specialized in one type of job.

### **Process Improvement Measures**

The production process on the future-state map exhibits significant overall improvements. Total construction duration of the value stream decreases from 65.5 work days to 38.5 workdays, amounting to a 27 workdays or over 5 weeks. The percentage of waiting time drops from 76 to 65% and the value added ratio increases from 17 to 26%. However, achieving the material flow envisioned in the future-state map requires that the amount of inventory on FIFO lanes should ideally be stabilized around six houses i.e., 3 workdays lead time and never less than four, so as to ensure that sub trades receive at least 2 work days notice. Based on the statistical analysis, PSS needs to be improved from current 45–77% to upward of 90% and with standard deviation of cycle time for each task reduced to 1 workday, so that the probability that the cycle times of any two homes in a series of six are longer than the average cycle time by more than 1 workday is below 10%. Although the actual probability of a shortage of jobs in the FIFO lane to fill the kanban lots might be much lower due to possible completion of previous delayed jobs, focused attention on improving the reliability of the operation of sub trades will be required.



**Lean Implementation**

The leader of the lean initiative has sufficient authority to allocate the organization’s resource sand to instigate changes across various functions and departments; the general manager of the company was designated as lean champion. A core lean team, including researchers, the president of the subsidiary company, construction managers, and site managers, was formed to lead daily lean activities.

A yearly kaizen plan was formulated to break implementation into steps and to provide a time frame for improvements. The objectives of each step were out lined as follows:

- Standardize work packages and educate the sub trades to eliminate handover problems;
- Implement total quality control to raise the yield rate to100%;
- Develop FIFO-lane-based flow from excavation through to drilling and pile placement with1 weeklead time;
- Develop an internet-based booking system;
- Establish supermarket-based pull flow between excavation and releasing of construction files;
- Restructure work packages depending on the availability of cross-function teams; and
- Reduce lead time between tasks to the levels how non the future-state map.

Naturally , these steps are not listed in sequence. Some of the mare in fact inter dependent and must occur

simultaneously .At the time of writing, a detailed construction procedure was developed in collaboration with construction managers, site managers, and all related trade contractors. As a result, the construction sequence has been completely standardized and the hand over problems caused by coordination issues dramatically reduced. As for FIFO- lane-based flow, nearly half of the sub trade contractors have agreed to use the lean booking system and have accepted 1week lead time .The analysis of production data from the 15 houses that passed through the value stream via FIFO lanes showed that total construction duration had been only slightly attenuated, but that the standard deviations of total duration and lead times handed - creased dramatically. All of this means that the implementation of the proposed model can significantly reduce process variability. Detailed discussion on results of the implementation, the strategy used by core lean team, lessons learned, and internet-based booking system will be reported on in future work.

## CONCLUSION

The housing construction process is a complex system that involves numerous interrelated tasks performed by various trade contractors. In current practice, houses in construction are treated as a collection of small projects using a conventional project management method. The conflict between predetermined schedule and unpredictable reality result insignificant wastes in the system. This research has focused on creating a stable production flow rather than laminating individual waste. VSM ,a powerful lean planning tool ,was use dto 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.

Detailed production data were collected through an intranet- based production tracking system and analyzed to assess cycle time, lead time, booking time, and percent started on schedule. Pushed scheduling and unpredictable process led to extremely long lead time and low PSS. Thus, creating a stable production flow became the top priority of future-state mapping. A FIFO- lane-based system was used, in tandem with production leveling at pacemaker task, in order to control the sources of fluctuation and to provide predictable flow to trade contractors.

Compared to the current state & the future-state demonstrate a remarkable improvement in overall performance. With a stable product flow, the capacity of each task is synchronized to takt time and fast response to sales change .The impacts of the changes proposed on the future-state map were investigate during simulation experiments. The implementation of the proposed lean system is ongoing, and a significant improvement in process reliability has been observed after the establishment of FIFO lanes.

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