

# Reduction and Elimination of Lean Waste Through Process Activity Mapping in Value Stream Mapping: A Simulation Analysis of Small Manufacturing Enterprises

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**Abstract.** Process activity mapping, a component of value stream mapping (VSM), is utilized to perform detailed process analysis to understand how to reduce and eliminate lean waste. Together with VSM, discrete event simulation is employed to confirm the effectiveness of improvements that cannot be directly observed in reducing and eliminating lean waste. This simulation study focuses on the reduction and elimination of lean waste through process activity mapping within VSM. Lean wastes were examined and developed using two simulation models: the current manufacturing system (CMS) and the revised manufacturing system (RMS), at both the macro and micro levels of VSM. The process activity mapping revealed that, out of the seven types of lean waste, four—unnecessary motion, inappropriate processing, transportation, and waiting—should be targeted to reduce and eliminate for supporting process improvement.

**Keywords:** Value Stream Mapping, Process Activity Mapping, Lean Wastes and Simulation.

## 1 Introduction

Value stream mapping (VSM) is a tool for macro-level analysis in manufacturing systems, utilizing key data points such as process, inventory, and time. It aims to identify and mitigate lean wastes ([1], [2]) at the macro level [3], enhancing efficiency within the manufacturing system [4]. Process activity mapping, a tool within VSM, is utilized for micro-level analysis of processes to comprehend the reduction and elimination of lean waste [5]. This tool includes charting activities like operations (O), inspection (I), storage (S), delay (D), and transport (T). Among the seven lean wastes, the process activity mapping tool is particularly effective in eliminating and reducing four lean wastes, such as transportation, waiting, inappropriate processing, and unnecessary motions [6] within the comprehensive process of VSM [7]. Along with VSM, discrete event simulation is utilized to validate proposed improvements unverifiable ([8], [9], [10]) for reduction and elimination of lean waste. This simulation study focuses on the reduction and elimination of lean waste through process activity mapping within VSM.

## 2 Method

The current manufacturing system (CMS) is mapped at the macro-level of VSM, utilizing data points like process, inventory, and time. Furthermore, CMS mapping is defined at the micro-level through process activity mapping within VSM. This includes charting activities like operations (O), inspection (I), storage (S), delay (D), and transport (T). By utilizing process activity mapping in VSM to analyze each step of the manufacturing process at a micro-level, the revised manufacturing system (RMS) enhances the CMS by eliminating and reducing lean waste, thereby reducing processing and lead time.

CellSim: Spreadsheet Factory™, a discrete-event simulation tool using Visual Basic Macro, is utilized to forecast improvements in reducing and eliminating lean waste. Lean wastes were analyzed using two simulation models, CMS and RMS. These models were developed through both macro and micro-level analysis of VSM with the aid of CellSim: Spreadsheet Factory. The CMS and RMS simulation models are employed to understand lean waste better. Suitable probability distributions were selected to simulate each process across various departments, such as cutting, assembly, and stitching. The CMS and RMS models underwent simulation for a period of 3600 seconds (1 hour), and the process was repeated three times. Key performance indicators like average throughput and resource utilization were evaluated for both CMS and RMS models.

### 3 A Simulation Analysis of Strap Manufacturing Process

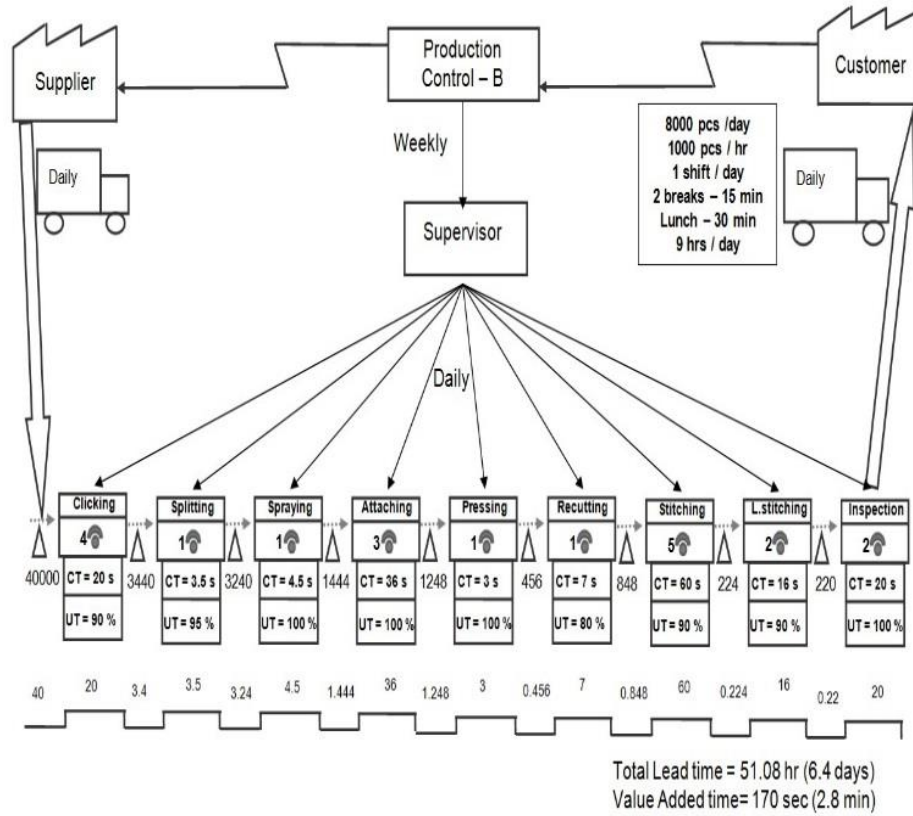
A small enterprise makes straps that must be processed in the following three main departments to understand the lean waste in the current manufacturing system (CMS):

- Cutting includes two processes for cutting strap materials and lining.
- Assembly includes four processes for the assembly of strap materials and lining.
- Stitching includes two processes for stitching strap materials and lining.

CMS mapping is conducted at the macro-level of VSM, utilizing data points like process, inventory, and time (Fig. 1.). Additionally, CMS mapping is delineated at the micro-level of VSM using process activity mapping for cutting (Tables 1) and assembly and finishing (Tables 2).

**Table 1** A micro-level analysis using Process Activity Mapping in VSM for the cutting process

Process Activity	O	I	S	D	T
Material Storage			S		
Loading of Material				D	
Moved to Cutting Dept					T
Unloading of Material				D	
Loading of Material in table				D	
Set up of clicking Machine				D	
Clicking Processing	O				
Unloading of Material Pieces				D	
Counting				D	
Moved to Splitting Process					T
Loading of Material Pieces				D	
Splitting Processing	O				
Material Pieces arrangement				D	
Wait for Material arrival				D	
Moved to Inspection					T
Inspection		I			
Counting				D	
Lot size arrangement				D	
Moved to store					T
<b>Total – Value Added</b>	<b>2</b>	<b>1</b>			
<b>Total – Non- Value Added (Waste)</b>			<b>1</b>	<b>11</b>	<b>4</b>



**Fig. 1.** A macro-level analysis using VSM for the current manufacturing system

**Table 2** A micro-level analysis using Process Activity Mapping in VSM for the assembly and finishing processes

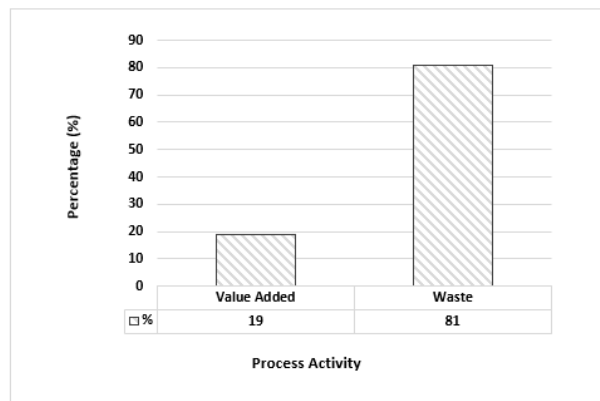
Process Activity	O	I	S	D	T
Store			S		
Wait for material in spraying				D	
Moved to Store					T
Loading of material in tray				D	
Placing of material					T
Moving to spray					T
Loading of tray in table				D	
Spraying	O				
Moved to attaching					T
Loading of tray				D	
Unloading of empty tray				D	
Foam attaching	O				
Moved to lining attaching					T
Lining attaching	O				
Moved to material attaching					T

<b>Process Activity</b>	<b>O</b>	<b>I</b>	<b>S</b>	<b>D</b>	<b>T</b>
Material attaching	O				
Counting				D	
Moved to Pressing					T
Feeding of material				D	
Pressing	O				
Unloading of material				D	
Moved to Recutting					T
Loading of material				D	
Picking the material				D	
Alignment of material in die				D	
Recutting	O				
Unloading of strap				D	
Picking the strap				D	
Moved to manual cutting					T
Loading of strap				D	
Manual Recutting	O				
Moved to Inspection					T
Inspection		I			
Moved to counting					T
Counting				D	
Lot size Arrangement				D	
Wait for strap arrival				D	
Moved to stitching					T
Loading of strap				D	
Stitching	O				
Placing the strap				D	
Moved to collect the strap					T
Picking the strap				D	
Loading of strap				D	
Thread cutting				D	
Moved to Inspection					T
Inspection		I			
Collecting the strap				D	
Loading the strap				D	
Labeling				D	
Moved to lock stitching					T
Alignment end to end				D	
Lock stitching	O				T
Moved to thread cutting				D	
Thread cutting				D	
Moved to flaming					T
Flaming				D	
Moved to Inspection					T
Inspection		I			
Arrangement of strap				D	
Collection of strap				D	
Counting				D	
Moved to packing					T

Process Activity	O	I	S	D	T
Packing	O				
<b>Total – Value Added</b>	<b>10</b>	<b>3</b>			
<b>Total – Non- Value Added (Waste)</b>			<b>1</b>	<b>32</b>	<b>19</b>

By utilizing process activity mapping in VSM to analyze each step of the manufacturing process at a micro-level, the revised manufacturing system (RMS) enhances the CMS by eliminating and reducing lean wastes, thereby reducing processing and lead time. Based on the process activity mapping, 19% are value-added activities and 81% are waste, i.e., non-value-added activities (Fig. 2). Waste can be classified into the following two categories:

- Waste, but necessary, such as loading, unloading, transportation, worker movement, set-up, and storage. This can be reduced in terms of cycle time by reducing the number of steps.
- Waste is not necessary, such as waiting, counting, and thread burning. This can be reduced in terms of lead time by removing the unnecessary processes.



**Fig. 2.** Determination of value-added activities and waste through process activity mapping

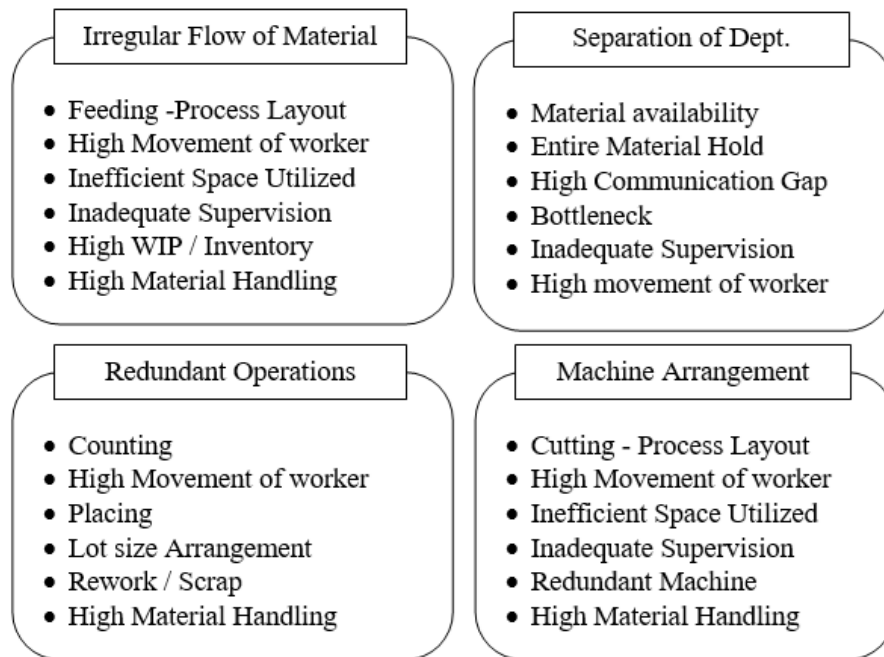
After micro-level analysis of the entire process in VSM, the following root causes are identified in CMS for the elimination and reduction of waste, which increases the cycle and lead time (Fig. 3):

- Irregular flow of material
- Separation of department
- Machine arrangement
- Redundant operations

RMS can eliminate and reduce lean waste by making the following process improvements based on the root causes:

- Product layout by integrating entire functions such as cutting, assembly, and stitching can reduce worker movement and work handling.
- In product layout, L-type flow for cutting and assembly and U-type flow for stitching can reduce worker movement and work handling.

- Redundant operations are removed to decrease the lead time.
- The efficient arrangement of machines can help reduce worker movement and work handling.



**Fig. 3.** Root causes in CMS for the elimination and reduction of waste

A simulation model of CMS was developed through macro-level and micro-level analysis of VSM using CellSim: Spreadsheet Factory for the cutting (Fig. 4), assembly (Fig. 5), and stitching (Fig. 6) departments. This CMS simulation model is utilized to comprehend lean waste. Appropriate probability distributions have been chosen to simulate each process in various departments, including cutting, assembly, and stitching.

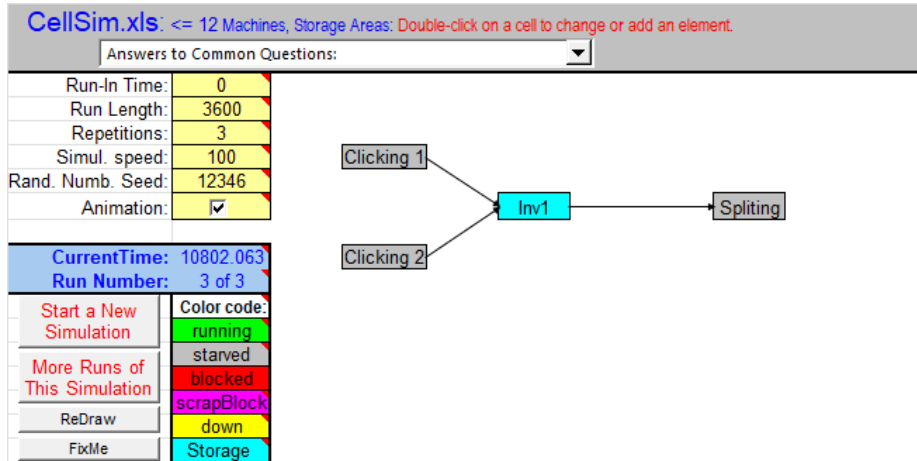


Fig. 4. Simulation Model of the Cutting Department

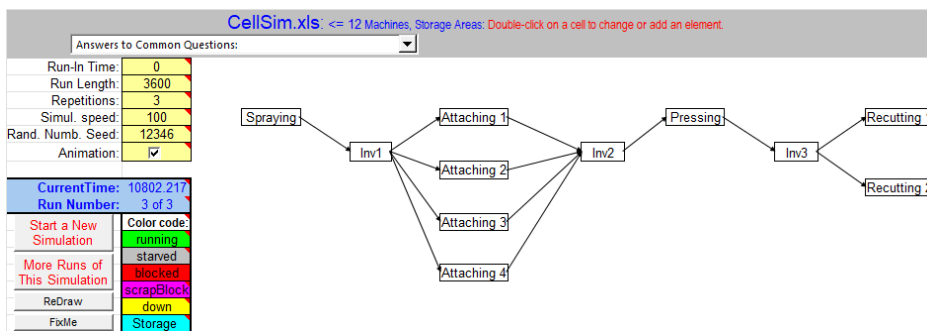


Fig. 5. Simulation Model of the Assembly Department

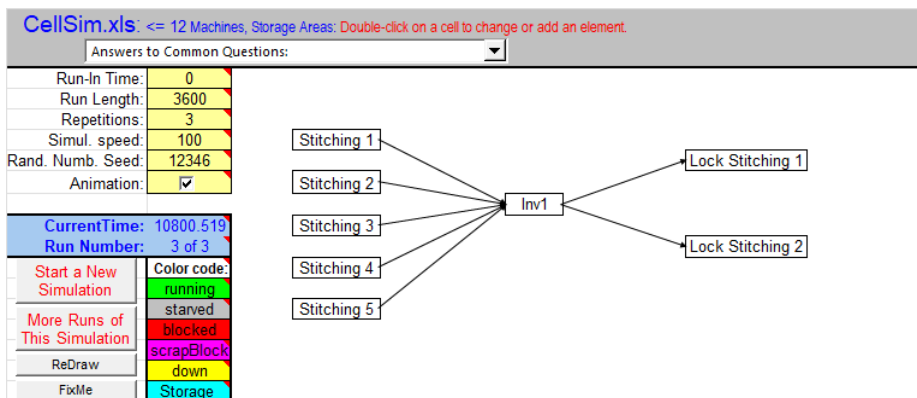


Fig. 6. Simulation Model of the Stitching Department

CMS model was simulated for a duration of 3600 seconds (1 hour), with the process being replicated three times. Performance metrics such as average throughput

and resource utilization were assessed for the CMS model. The cutting department's average throughput is 2324 units per hour, the assembly department's is 2540 straps per hour, and the stitching department's is 3384 straps per hour. The RMS model was simulated for a duration of 3600 seconds (1 hour), with the process being replicated three times. Performance metrics such as average throughput and resource utilization were assessed for the RMS model. The cutting department's average throughput is 3096 units per hour, the assembly department's is 4036 straps per hour, and the stitching department's is 4332 straps per hour. Fig. 7 presents a comparison of the simulation outcomes for CMS and RMS. It shows that the average throughput for RMS exceeds that of CMS in the departments, attributed to the elimination and reduction of lean waste. Fig. 8 displays the percentage of resource utilization derived from the simulation model for CMS and RMS operations. The resource utilization for the entire RMS operation is greater than that of CMS, except for the clicking and lock stitching operations, which have a shorter cycle time.

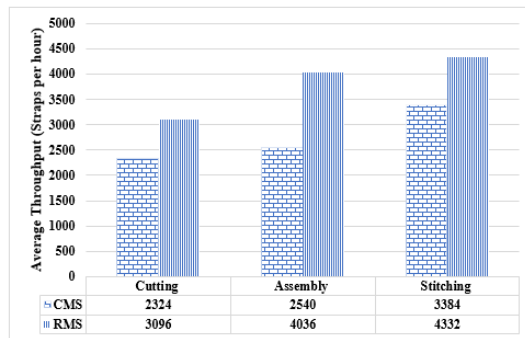


Fig. 7. Average throughput for each manufacturing system based on each department

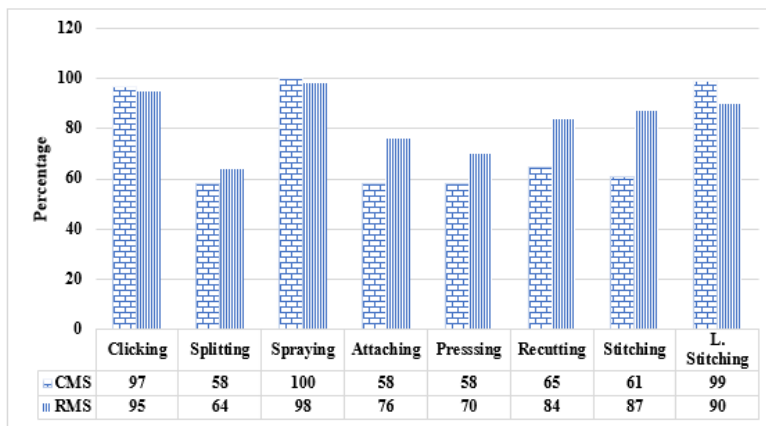


Fig. 8. Resource utilization for each manufacturing system based on each process

## 4 Conclusions

The process activity mapping tool identified that among the seven lean wastes, four—unnecessary motion, inappropriate processing, transportation, and waiting—need to be eliminated and reduced to enhance process improvement. The simulation results indicate that the average throughput for RMS surpasses that of CMS across the departments, which can be ascribed to the minimization and elimination of lean waste. Moreover, the resource utilization for the entire RMS operation is higher than that of CMS, except for the clicking and lock stitching operations where the cycle time is reduced. The process activity mapping tool, utilizing data on average throughput and resource utilization, has provided a clearer insight into the elimination and reduction of lean waste within VSM at a micro-level analysis.

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