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Productivity Improvement in Bus Body Manufacturing Using Value Stream Mapping and Line Balancing Technique

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Abstract: *Bus body manufacturing play a key role in automotive manufacturing, as vehicle manufacturers often sub contract such enterprise to complete bus manufacturing process. In a fiercely competitive global environment, the bus body manufacturing enterprises are constantly looking for ways of meet their customer requirements of delivery on time, cost and quality in order for them to survive. However, bus body manufacturing enterprises barely meet the customer demands in terms of delivering on time due to long cycle times on the production floor due to low labour utilization, material wastage and unorganized work flows. In this research, we critically looked at improving productivity such enterprises by considering a case study of one of the leading bus body manufacturing enterprises in Kenya. Value Stream Mapping was used as the main productivity improvement tool supported by line balancing techniques. The results from the improved value stream map indicated an increase in efficiency of 13.1% and a reduction the cycle time by 7 days, demonstrating the potential of these tools for improving productivity in bus body manufacturing.*

Keywords - *Value Stream Map, Line Balancing, Cycle Time Takt Time*

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I. INTRODUCTION

The manufacturing sector today faces stiff completion with customers demanding quality products delivered at a shorter time and at a competitive price. This calls for manufacturers and more so in the automotive sector to improve productivity in order for them to remain competitive [1]. This has made productivity improvement one of the main areas of focus and various tools such as Value Stream Mapping (VSM), Line balancing and Simulations have been employed to achieve this [2].

VSM is a concept that helps the firm and all employees to identify wastes, demonstrate and reduce them. Extensive research has been done on VSM, and seen as a tool used to analyse material and information flow in a manufacturing process [3]. The aim of VSM is to enable firms to see the whole production process not only in terms of material flow but also information flow [4]. VSM can thus serve as a starting point to help management, engineers, production associates, schedulers, suppliers, and customers recognize waste and identify its causes at a glance [5].

With the ever-rising customer requirements, often the firms find themselves not delivering to the customer on time and hence continuously encountering rising productions costs at the same time. Automotive body manufacturing small-scale firms with limited capacities experience a myriad of problems in their production systems such as:

1. Delays is in the framing stage due to unavailable or delays in supplying the raw material (Steel)
2. Completed framed bodies waiting to move to the paneling stage
3. Completed bus waiting to move through the paint shop
4. Accumulation of scrap at various stages of fabrication across the plant

For bus manufacturing, global demand for buses is projected to reach 664,000 units in 2018, increasing by 5 per cent annually up to 2021 majorly driven by the increasing urban population. To keep pace with the demand, and owing to the fact that production inefficiencies and wastes in the production systems of bus body manufacturing cuts across all bus body manufacturing companies [6], it will be neccesary for bus body manufacturing firms to improve their throughputs, reduce production cycle times and lower manufacturing costs. Therefore, productivity improvement is no longer an option but a priority for such firms. The purpose of this research work is to use VSM and line balancing to improve productivity in bus body manufacturing industry by reducing production cycle time.

II. LITERATURE REVIEW

The goal of manufacturing is to create and add value to the inputs during the transformation [7]. Manufacturing systems are characterized by multiple workstation or machines whose operation are interconnected by material handling systems that allow for movement of parts, finished products or semi-finished products between stations [8].

The variety in bus body manufacturing and specific customer requirements has contributed to limited automation in bus body manufacturing enterprises. This coupled with extensive manual labour in this industry have created a challenge in productivity improvement initiatives. In meeting this challenge, selection and control of appropriate manufacturing systems is critical. This is to ensure that the firm produces more with less material, less labour and less energy [9]. Bus body manufacturing in developing countries is characterized by low volume and job shop is often used to describe such type of production facility where products are specialized, customized and normally complex [10]. The complexity of the job in such environment requires general-purpose equipment and highly skilled personnel [11]. Beyond complexity, a job shop must be designed for maximum flexibility to deal with the wide product variations encountered. Therefore, the job shop must deal with different types of flexibilities but more so deal with operation flexibility [12]. Beyond the value addition, content to the input, reduction of cost can equally improve productivity [13]. In addressing productivity, the aim of the process is to reduce the non-value activities in order to optimize the output and this is one of the key strategies in manufacturing excellence initiatives [2].

VSM has extensively been used to improve productivity. Originally, VSM was applied in automotive manufacturing but the same has be applied in other sectors of production such as aircraft manufacturing [14], digital manufacturing [15]. Key to VSM is the identification of Value Adding (VA) processes and Non Value Adding (NVA) process, and focusing on reducing the NVA. For a long time VSM was constructed by pencil and paper, but computer software has made it easier especially in the last decade. One well established software is the quality companion by Minitab [16].

In manufacturing, assembly lines are very common. However, bottlenecks often occur due to difficulties in getting the line balanced thereby creating wastes related to defects, work in progress, overproduction and waiting [17]. Bottlenecks can be alleviated by identifying and eliminating non-value adding activities, making changes in workstation and elimination of unwanted operator movements with the aim of improving productivity. Works study methods and line balancing techniques have been used in manufacturing to improve productivity in link and roller assembly [18]. Line balancing is a technique used to minimize imbalance among workers and workloads in order to achieve the required run rate, and hence reduction in operator requirement and increased output.

III. RESEARCH METHODOLOGY

The case study approach was used for this research with in depth interviews, observation and data mining [19]. We focused on a full analysis of a limited number of events or conditions and their interrelations i.e. dealing with the processes that took place and their interrelationship. We intensively studied process cycle times for each individual bus body manufacturing process and thus shedding light on a large class of similar units [20]. That approach helped us to understand the real processes in bus body manufacturing firm and how that led to the results.

To gather the required data, identified production operators were observed during the production of buses at each workstation. That enabled details and notes taken for each process. Each step in the process was written down separately, together with relevant data such as the time it took to perform that step, the amount of people involved and the time used for waiting or moving. Furthermore, each step was categorized to differentiate between Value Added (VA) and Non Value Added (NVA) time. All processes that add value from the customers' perspective were recorded as VA. Motion, installation of machines/set up, inspections, waiting for another process to be completed, were recorded as NVA. No company historical data existed on this measurement and therefore, we used a stopwatch, pencil and paper watch. Due to the nature of the work, the timing was approximated to the nearest hour. We observed the operators at each station as they performed their work and recorded the total time for the NVA, which included moving to collect material, searching and waiting for the tools to be brought and resting without doing work when not being closely supervised.

The validity of the data collected was influenced by the presence of the observer as that affected the workers' natural performance. A discussion with the workers was done to assure them that they should feel free and perform their duties normally. In creating the Value Stream Maps, we followed the steps as detailed in Fig.1.

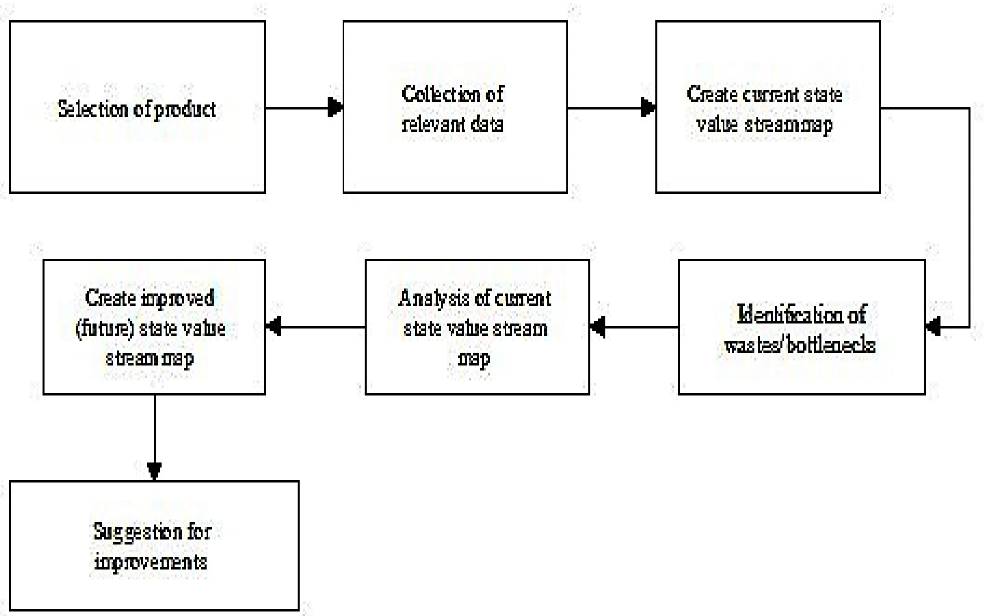

Figure 1: Steps for implementing VSM

IV. RESULTS AND ANALYSIS

From the case study, the bus manufacturing processes were identified as shown in Fig.2.

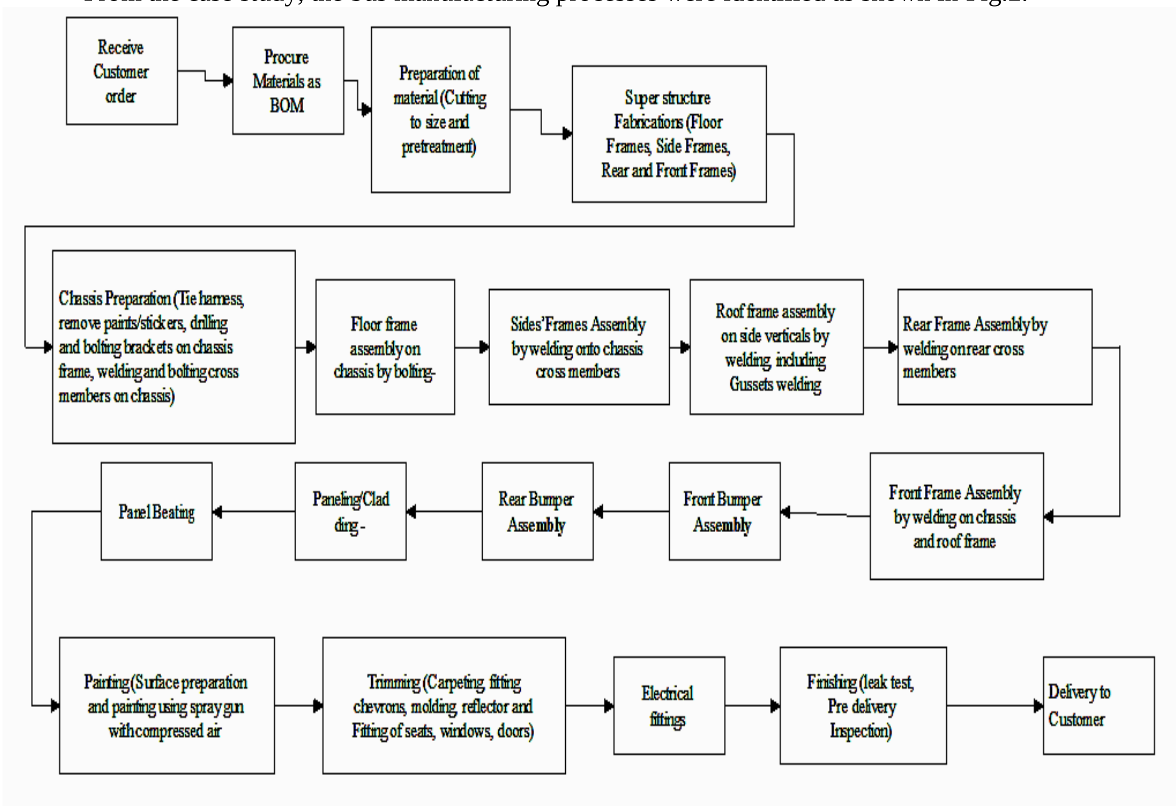

Figure 2: Bus body manufacturing process flow

The data collected for each process is summarized in the Table 1.

Table 1: Raw Process Data

Process	Number of operators	Cycle time (days)	Cycle time (hours)
Preparation of materials	6	5	40
Floor frame fabrication	2	2	16
Right side frame fabrication	2	2	16
eft side frame fabrication	2	2	16
Roof frame fabrication	2	2	16
Chassis preparation	2	2	16
Floor frame assembly	2	1	8
Sides' frame assembly	2	3	24
Roof frame Assembly	2	3	24
Rear and front frame assembly	2	3	24
Bumper Assembly	2	1	8
Paneling/Cladding	2	4	32
Panel beating	3	3	24
Painting	2	5	40
Fitting and Trimming	5	6	48
Electrical fittings	2	3	24
Finishing	2	2	16
Total	**42**	**49**	**392**

4.1 Current State Value Stream Map

The VA and NVA times were separated from the cycle time recorded in Table 1 and the summarized data is given in Table 2.

Table 2: Process cycle time for bus body manufacturing

Process	Number of operators	Cycle time (days)	Cycle time (hours)	Non Value Add Time (Movement and Waiting)
Preparation of materials	6	5	40	10
Floor frame fabrication	2	2	16	6
Right side frame fabrication	2	2	16	4
Left side frame fabrication	2	2	16	4
Roof frame fabrication	2	2	16	4
Chassis preparation	2	2	16	3.5
Floor frame assembly	2	1	8	1
Sides' frame assembly	2	3	24	6
Roof frame Assembly	2	3	24	7
Rear and front frame assembly	2	3	24	6
Bumper Assembly	2	1	8	0.5
Paneling/Cladding	2	4	32	8
Panel beating	3	3	24	7
Painting	2	5	40	8
Fitting and Trimming	5	6	48	7
Electrical fittings	2	3	24	4
Finishing	2	2	16	2
Total	**42**	**49**	**392**	**88.5 (Approx. 89)**

With the help of Table 2, the current state value stream map was drawn as given in Fig. 2.

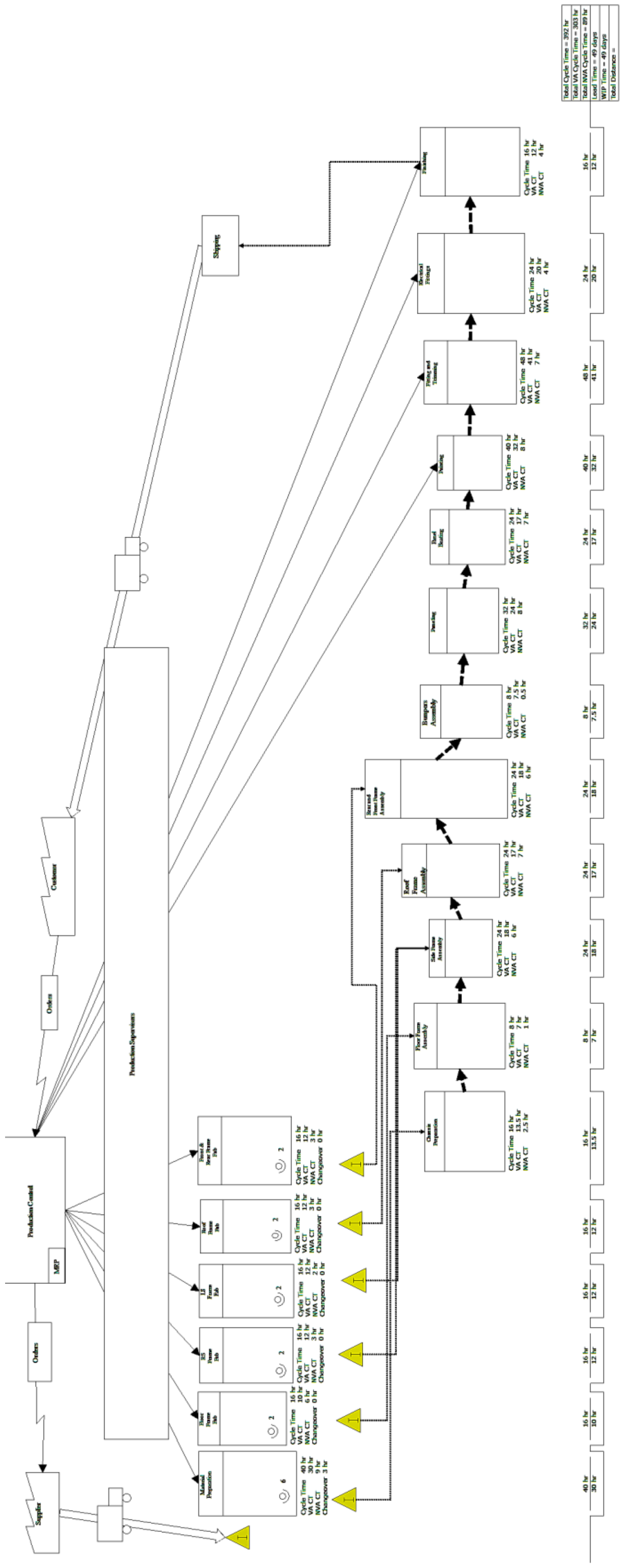

Figure 2: Current State Value Stream Map

4.2 Improved (Future) State Value Stream Map

In developing an improved (future) state value stream map, we determined the cycle time, value added time and cycle efficiency (line balancing).
From Table 1, the cycle time is 48 hours (the process with the highest processing time).
Takt time was calculated as follows:
Available production time per month = 45 hrs per week * 4 weeks = 180 hours.
Customer demand = 10 buses /month
Takt time = Available production time per month/demand per month = 180/10
= 18 hours/per bus
Using line balancing technique, from Table 2 the line balance efficiency was calculated as follows:
Total work content = 392 hours
Number of operators = 42
Cycle time = 48 hours
Therefore,
Production efficiency = Total work content/ (No. of operators * cycle time)
= 392/(42*48) = 0.1944
Balance delay = 1- 0.1944 = 0.8056

Using Table 1 and the calculated takt time of 18 hours, the process graph showing takt time in comparison with the cycle times for each process is shown in Fig. 3.

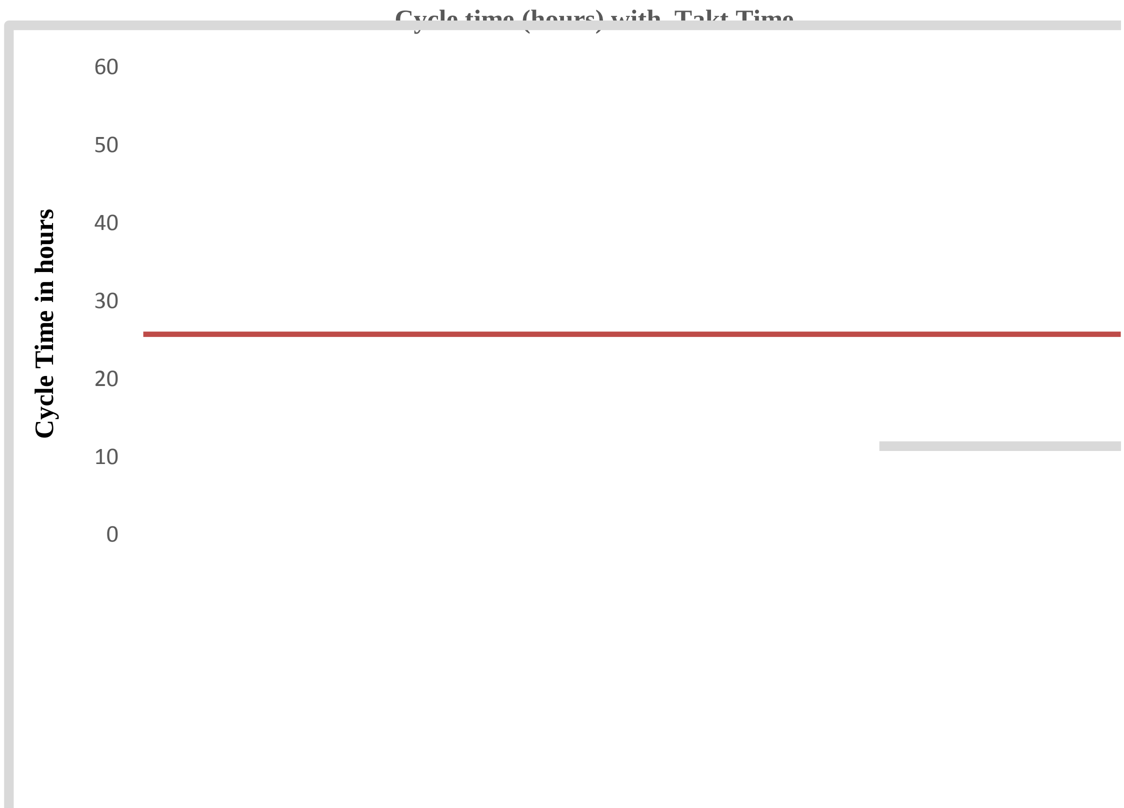

Figure 3: The process chart with takt time

Fig. 3 was important in determining what, when and how to improve in future steps and how the future state value stream map will look like. We focused on activities whose cycle times are above the takt time. We therefore prioritized the four key process as bottlenecks to focus on as follows:

1. Fitting and Trimming
2. Materials preparation
3. Painting
4. Paneling/cladding

It was equally important, to look at the activities with the lowest cycle time and combine some of them. Assessment of the process showed that we could combine the processes from floor frame fabrication to

bumpers' assembly and call it superstructure construction process, since they were using the same operators and equipment and the process steps are very similar.
The next step was to calculate the optimum operators required.

Optimum number of operators = Total cycle time /takt time
= 392/18
= 22 Operators.

The new superstructure process cycle time was calculated as follows.

Total number of initial processes = 10
Initial total cycle time = 208 hours
New total cycle time required = takt time * number of processes
= 18 * 10
= 180 hours

With the assumption that all the operators are equally qualified and multi skilled, we redistributed the number of operators across the processes appropriately in order to reduce the cycle times. For the four bottleneck processes, for instance in fitting and trimming, increasing the number of operators to four brought down the cycle process time to 24 hours. Similarly, for material preparation, increasing the number of operators to 10 brought cycle time down to 20 hours. For painting and cladding process, the cycle times came down to 20 hours and 24 hours with 10 and 3 operators respectively. By reducing the cycle times, it was also observed that the Non Value Added times reduced by half across all the processes.

The complete redistributed operators and cycle times was as given in Table 3,

Table 3: Line Balanced Process Cycle Time

Process	**Number of operators**	**Cycle time (hours)**	**Non Value Add Time (Movement and Waiting)**
Preparation of materials	10	20	5
Super Structure construction (10 Operations combined).	11	180	22
Paneling/Cladding	3	24	4
Panel beating	4	20	3
Painting	4	20	4
Fitting and Trimming	6	24	4
Electrical fittings	2	24	4
Finishing	2	16	2
Total	**42**	**328**	**48**

The improved (future) state value stream is shown in Fig. 4.

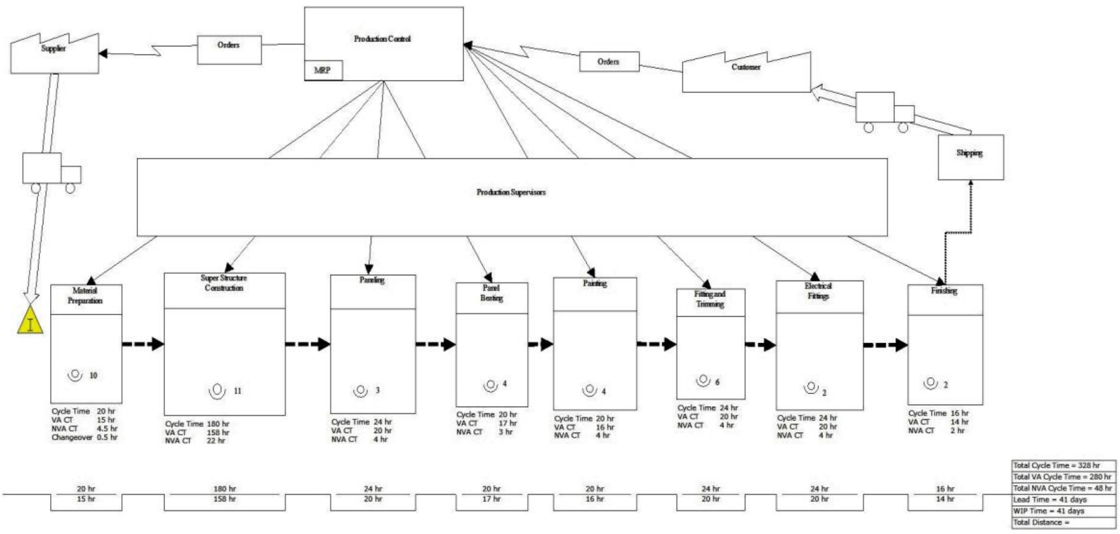

Figure 4: Future State Value Stream Map

Comparing the current value stream map and the improved (future) value stream map, it was observed that the line was better balanced and synchronized with takt time as shown in Fig. 5 and Fig. 6 respectively.

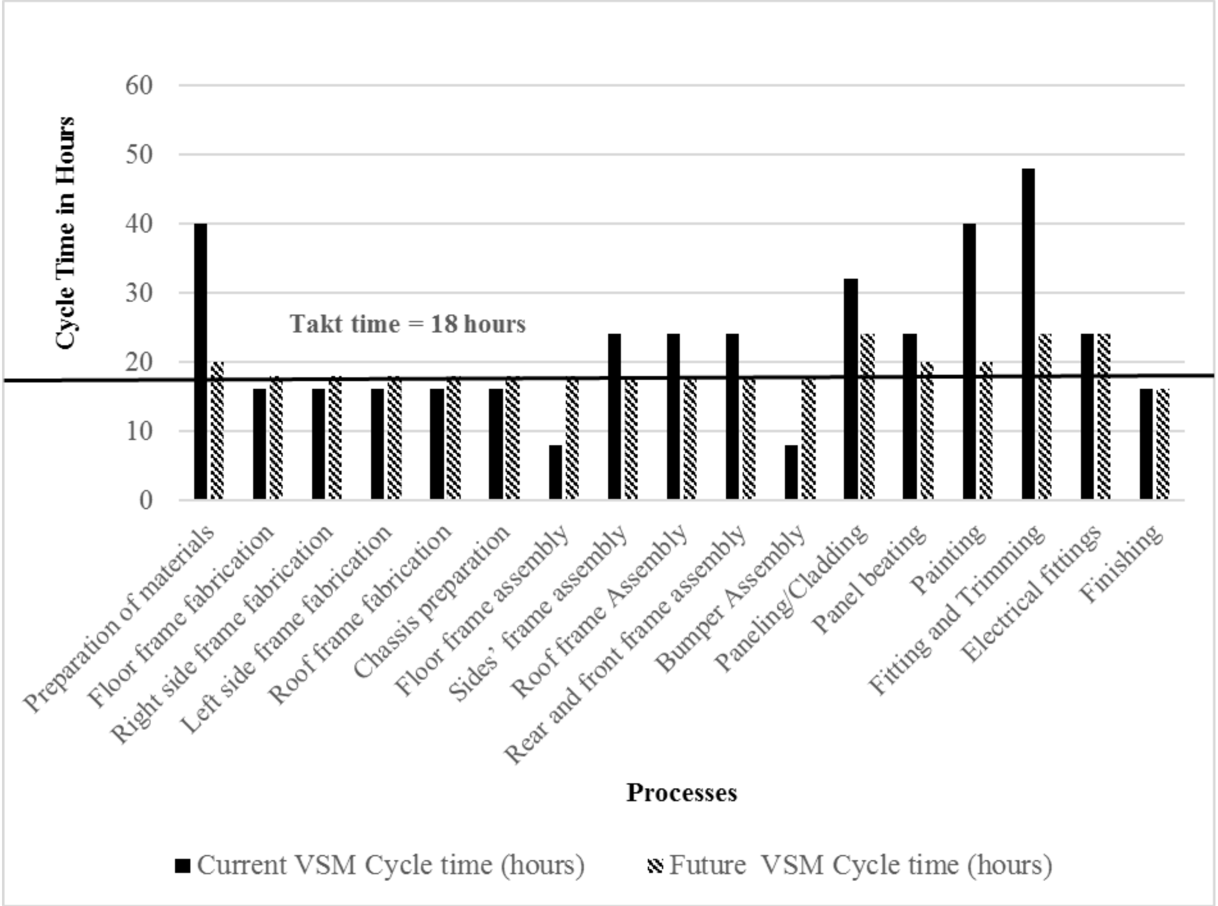

Figure 5: Comparison of the cycle time (hours) for the current VSM and proposed (future) VSM

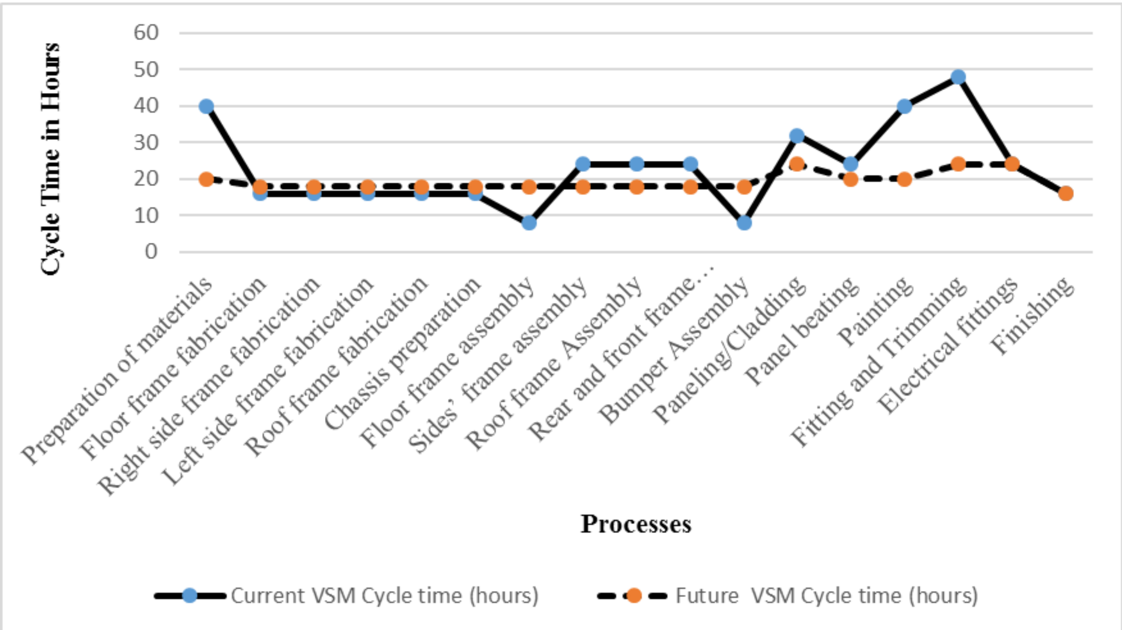

Figure 6: Balanced line comparison of the cycle times with takt time for the current VSM and Improved (Future) VSM

V. CONCLUSION

Productivity in bus body manufacturing industry can be improved by combining a number of tools. Value Stream Mapping is fundamental in understanding the current state of production and provides a good start for finding the bottlenecks. By analyzing the bottlenecks, ways of eliminating them can be found leading to an improved future state map. In the effort of continuous improvement, the developed future state map becomes the current state and the cycle can be repeated to create further improvement in production. This research in practice changes the way bus body manufacturing firms carry out their production processes by looking at the entire system rather than looking at isolated processes and trying to solve those isolated operations.

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