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Process Cycle Efficiency Improvement Through Lean: A Case Study

D. Rajenthirakumar*
Department of Mechanical Engineering, PSG College of Technology, Coimbatore, 641 004, India
E-mail Adres: rajentkumar@gmail.com

P.V. Mohanram
Department of Mechanical Engineering, PSG College of Technology, Coimbatore, 641 004, India

S.G. Harikarthik
Department of Mechanical Engineering, PSG College of Technology, Coimbatore, 641 004, India

ABSTRACT

Lean manufacturing is an applied methodology of scientific, objective techniques that cause work tasks in a process to be performed with a minimum of non-value adding activities resulting in greatly reduced wait time, queue time, move time, administrative time, and other delays. This work addresses the implementation of lean principles in a construction equipment company. The prime objective is to evolve and test several strategies to eliminate waste on the shop floor. This paper describes an application of value stream mapping (VSM). Consequently, the present and future states of value stream maps are constructed to improve the production process by identifying waste and its sources. A noticeable reduction in cycle time and increase in cycle efficiency is confirmed. The production flow was optimized thus minimizing several non-value added activities/times such as bottlenecking time, waiting time, material handling time, etc. This case study can be useful in developing a more generic approach to design lean environment.

KEYWORDS

Lean Manufacturing,
Value stream mapping,
Cycle time,
Takt time,
Cycle efficiency.

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* Corresponding Author

1. Introduction

Lean manufacturing is based on the Toyota Production System developed by Toyota which focuses on eliminating waste, reducing inventory, improving throughput, and encouraging employees to bring attention to problems and suggest improvements to fix them (Womack et al. 1991). Lean manufacturing has increasingly been applied by leading manufacturing companies throughout the world. A core concept of lean manufacturing is pull production in which the flow on the factory floor is driven by demand from downstream pulling production upstream. Some of the changes required by lean manufacturing can be disruptive if not implemented correctly and some aspects of it are not appropriate for all companies (Hobbs, 2004). A lean manufacturing facility is capable of producing product in only the sum of its value added work content time. Features of a typical lean manufacturing model include: one unit at a time production, non-value added time eliminated, production in the work content time only, and relocation of required resources to the point of usage.

In the present day of manufacturing, assembly line can be formed easily for any industry whether it is a small-scale or a large-scale industry. When the takt times are calculated for every part manufactured in the industry through different part movements, then the problem of locating machines on the shop floor occurs when it is a job type production unit; this problem is the main reason for reconfiguration of machines and layout design for every demand. To eliminate these problems, a proper method is required to achieve a rhythm in manufacturing lean assembly line by identifying value adding, non-value adding, and necessary non-value adding activities through an optimum feasible takt time.

This paper presents a case study of a large-scale construction equipment manufacturing industry facing the problems as discussed above. This work addresses the implementation of lean manufacturing on the construction equipment assembly, with a focus on the activities of paint shop which should have a proper rhythm of assembly line, minimizing wastages like bottleneck time, waiting time, material handling time, etc. The prime objective is to develop different strategies to eliminate waste. The lean tool value stream mapping (VSM) applied as a method to lead the activities.

2. Literature Review

Currently, assembly lines are still fundamental to get the smoothing of production system (Miltenburg, 2001), and they are studied under several operative perspectives seeking its flexibility (El-Maraghy, 2005; Calvo et al. 2007). Both concepts are subjects of pull systems. In assembly lines, pull and lean systems are concepts frequently connected, although they pursue different objectives; pull system toward the reduction of work-in-process (WIP) and lean system toward minimizing the buffer variability (Hopp and Spearman, 2004). Moreover, with respect to the election of production control system in a pull system, the alternatives considered are focused on kanban (Monden, 1998) and constant work in process (CONWIP) (Spearman et al. 1990), both of them focused toward the reduction of WIP.

Although many tools exist, from its origin, VSM has demonstrated its efficacy (Womack and Jones 1996; Sullivan et al. 2002; Abdulmalek and Rajgopal 2007; Serrano et al. 2008; Sahoo et al. 2008). Following the benchmarking perspective, as well the use of a contrasted tool, facilitates the interchange of improvements. It is a tool that provides communication solutions for practitioners to obtain maximum efficiency and definitions of theoretical development points to become a reference among redesign techniques (Serrano et al. 2008). A detailed description of VSM can be seen in Rother and Shook (1999). Thus, as improvement tool simplifies the measurement of times without added value, so the calculation of indexes of lean metrics is easier and it is possible to enhance the operative actions with strategic results.

This paper unifies several gaps and it shows how value stream transformation actions can achieve high levels of performance in a short time and in a real industry, inside a context of an assembly line with a small space and that it requires flexibility.

3. Problem Definition

This work deals with the end to end perspective of reducing waste at an assembly line paint shop of a construction equipment manufacturing company. The major tasks involved in the paint shop are sketched in Figure 1 and the layout is given in Figure 2.

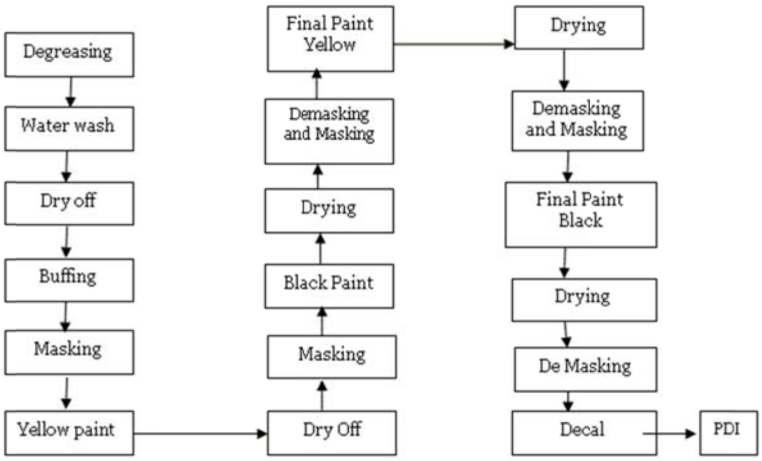

Figure 1. Major tasks in the assembly line paint shop

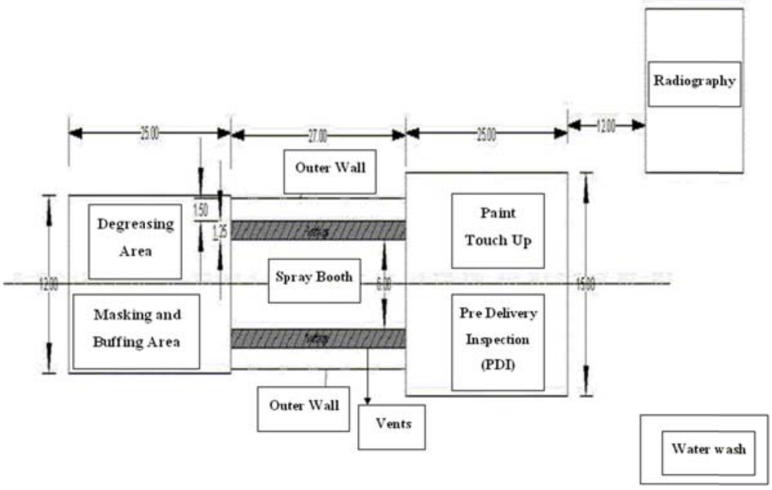

Figure 2. Layout of the assembly line paint shop

After intense brain storming and a thorough study of the paint shop, it was observed that the paint shop activities contain various forms of non-value-adding activities as follows:

- Drying which takes eight hours increases cycle time
- Paint shop floor space insufficient for 100 tones
- Inadequate lighting (850 lux)
- Paint coagulation
- Ineffective blower performance

Certainly, all of these factors lead to high production lead time. In the existing conditions, the average production lead time is found to be around 9688 min and the cycle efficiency is found to be 3%, which is not sufficient.

4. Lean Implementation

In order to implement lean principles, a task group was formed with people from different parts of the organization, all having rich knowledge and information pertaining to process, production, equipment and planning. The objectives of the operation were (i) to reduce the level of non-value activities present in any form by implementing the various lean tools (ii) to reduce the overall process time of the assembly line paint shop through improvements in the water wash, masking, drying processes and eliminating over processing of final black paint (iii) to introduce a safety trolley for masking radiator cover and (iii) to increase the cycle efficiency. The methodology adopted to achieve the objectives is given in Figure 3.

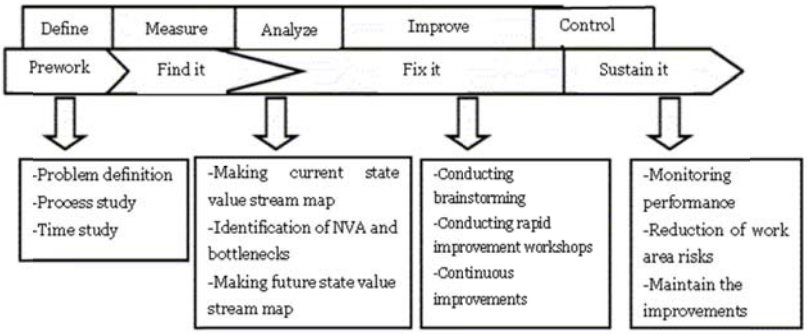

Figure 3. Methodology for lean implementation

4.1 Current state value stream mapping

To construct the current state value stream map, relevant information was collected by interviewing people on the paint shop floor. As a pre-work, process and time study was performed and Table 1 summarizes the overall activities associated with the paint shop along with their processing time. Data relevant to the customer, such as quantity to be delivered, delivery time were observed and information related to the assembly line, such as processing time, inventory storage, inspections, rework loops, number of workers and operational hours per day were collected and documented properly. To complete the value map, a timeline is added at the bottom of the map recording the lead-time and the value-added time. Eventually, the value stream map for the current state is constructed as shown in Figure 4.

Table 1. Current state paint shop processes and processing time

Name of the process	Average processing time in minutes	Name of the process	Average processing time in minutes
De-grease	15	De-masking	10
Water wash	60	Painting: yellow	60
Dry off	55	Drying	290
Buff	45	De-masking	26
Mask	40	Painting: black	35
Yellow paint	120	Drying	120
Dry off	240	De-masking	15
Mask	10	Decal	35
Black paint	20	PDI/rectification	30
Drying	60		

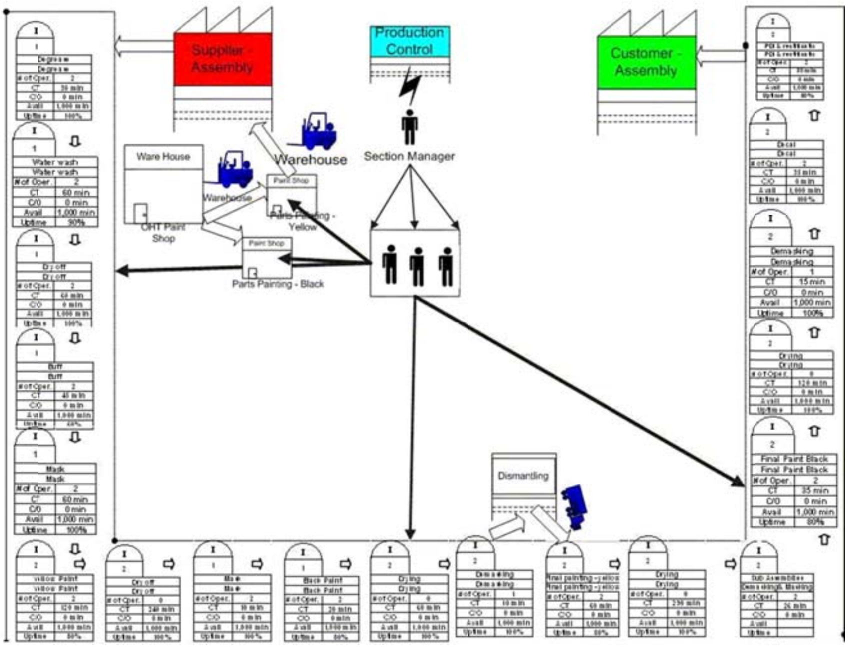

Figure 4. The present value stream map

As observed from the value map, various value-added activities present in the flow line, bottlenecks are identified and quantified in time, as shown in Figure 5 and Table 2. It is found that about 293.80 min, or 22.85% out of 1286 min, were value added activities, compared to 992.2 min or 77.15% of non-value added activities. It is concluded that the drying process is the major issue which is not within the current levels of demand. If the growing levels of demand increases, drying is not within the takt time.

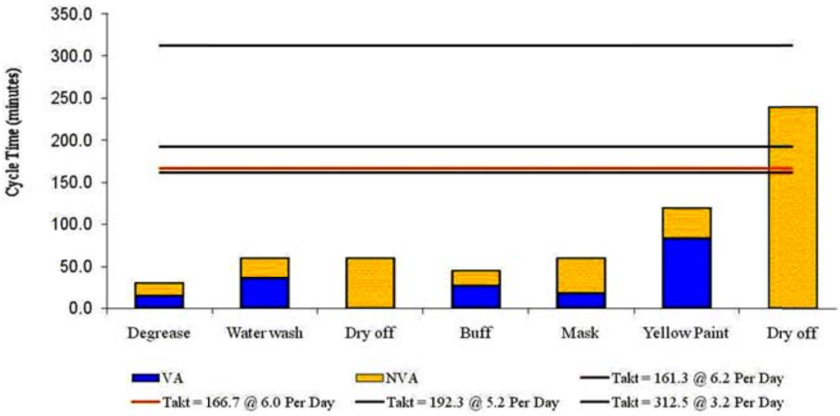

Figure 5. The present state VA/NVA time

Table 2. Current state VA/NVA time analysis

Name of the process	%VA	VA time (min)	NVA time (min)	Average processing time in minutes
De-grease	60%	9.00	6.00	15
Water wash	60%	36.00	24.00	60
Dry off	0%	0.00	55.00	55
Buff	60%	27.00	18.00	45
Mask	30%	12.00	28.00	40
Yellow paint	70%	84.00	36.00	120
Dry off	0%	0.00	240.00	240
Mask	30%	3.00	7.00	10
Black paint	70%	14.00	6.00	20
Drying	0%	0.00	60.00	60
De-masking	60%	6.00	4.00	10
Painting: yellow	70%	42.00	18.00	60
Drying	0%	0.00	290.00	290
De-masking	30%	7.80	18.20	26
Painting: black	70%	24.50	10.50	35
Drying	0%	0.00	120.00	120
De-masking	50%	7.50	7.50	15
Decal	60%	21.00	14.00	35
PDI/rectification	0%	0.00	30.00	30

4.2 Tact time

Tact time can be defined as the time required producing one unit of daily salable quantity. To calculate tact time in the context of present problem, the average demand per two shifts was found to be 3.2 units of components under study. The company runs for two shifts, 500 min per shift excluding break time. This results in a tact time of nearly 312.5 min. Therefore, it is concluded that one unit of product must come out during every 312.5 min interval.

4.3 Total cycle time and cycle efficiency

Reducing the lead time in any production system is a continuous improvement process. While addressing the problem, the production lead time for the existing conditions was first calculated. The various components associated with lead time are identified separately and different practical strategies are adopted for improvement. In general, the various components associated with the lead time of any production process are (i) Waiting time before process (ii) Setup time (iii) Process time (iv) Waiting time after process (v) Transfer time. Considering all the elements involved, a total cycle time of 9687.50 minutes was calculated.

Also, the total cycle efficiency involved in the process is found to be approximately 3.2%. In order to reduce the total cycle time and increase the cycle efficiency, various strategies such as problem identification, data documentation, motion and time study, improvements made, operation sheet review, and continuous monitoring are adopted.

Initiatives taken to increase the cycle efficiency are:

- Standard work sheet is prepared
- Warm water is utilized to facilitate quicker drying process
- Permanent mask using rubber material designed to facilitate better functioning
- Stringent monitoring is done and improvement opportunities are addressed in time
- Wherever possible, inefficient operations are eliminated; for example, oven drying process is developed
- To handle higher capacity, construction equipment layout modification was done
- To improve operator safety, safety trolley was designed for masking process

4.4 Reducing time for masking process

To Reduce the masking time, permanent mask using rubber material was designed which in turn reduces the cost of masking. The improvements are shown in Figure 6.

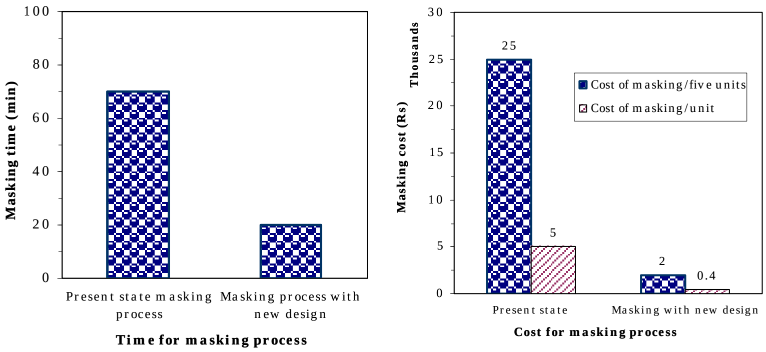

Figure 6. Masking process time reduction

4.5 Improvement of drying process

As a part of improved drying process, warm water was used for water washing of the equipment which results in 58% of time savings. From the current state analysis, it was clear that the drying process was the major bottleneck. In the present state, drying process was carried out outside the paint shop by allowing the unit to dry in hot sun which took 16 hours to complete. Also time amounts to 650 minutes on an average was spent for paint drying operation which included yellow painting, black painting and final yellow painting. Instead ovens of LPG type were introduced for drying process and the process time was decreased to 240 minutes. The improvement is shown in Figure 7.

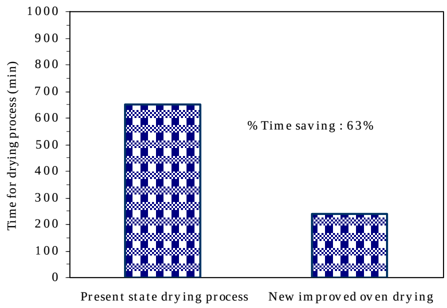

Figure 7. Improved drying process

4.6 Improvement in safety

It was found that the operator masks the unit by standing in the bumper of the construction equipment which is unsafe as shown in Figure 8. As a part of safety risk assessment, a new trolley was designed for masking radiator cover, where the operator stands near the corner of the equipment. By using the newly designed trolley, the operator is able to mask the radiator easily without any issues as shown in Figure 9. Since the trolley was developed using scrap materials, the labour cost is the only cost element associated with the new safety equipment.

Figure 8. Present state masking-operator risk involved

Figure 9. Masking with safety trolley-operator risk eliminated

4.7 Future state value stream mapping

Finally, the future state value stream map is constructed as shown in Figure 10, which reported a considerable depletion in non-value-added time. A drastic reduction in time for drying process is also observed. Furthermore, the process lead time is reduced to 725 min as illustrated in Figure 11. Table 3 outlines the value stream analysis report for the future state. It is found that about 554 min, or 76.4% out of 725 min, were value-added activities compared to 171 min or 23.6% of non-value-added activities. Comparing the value maps, it can be concluded that a 821.2-min reduction in non-value-added activities is achieved. Figure 12 depicts the various benefits made after the implementation of lean.

Table 3. Future state VA/NVA time analysis

Name of the process	%VA	VA time (min)	NVA time (min)	Average processing time in minutes
De-grease	80%	12.00	3.00	15
Water wash	80%	48.00	12.00	60
Dry off	100%	60.00	0.00	60
Buff	80%	36.00	9.00	45
Mask	80%	12.00	3.00	15
Yellow paint	70%	84.00	36.00	120
Dry off	100%	120.00	0.00	120
Mask	80%	4.00	1.00	5
Black paint	70%	14.00	6.00	20
Drying	50%	30.00	30.00	60
De-masking	70%	7.00	3.00	10
Painting: yellow	70%	42.00	18.00	60
Drying	50%	30.00	30.00	60
De-masking	50%	5.00	5.00	10
Decal	100%	35.00	0.00	35
PDI/rectification	50%	15.00	15.00	30

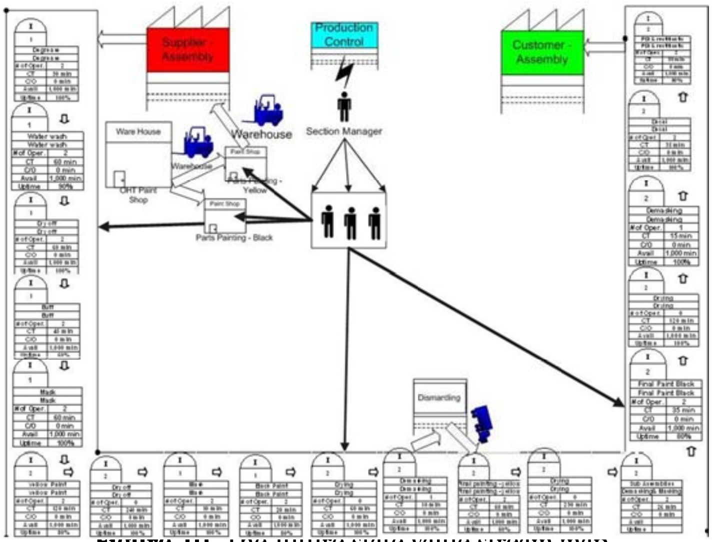

Figure 10. The future state value stream map

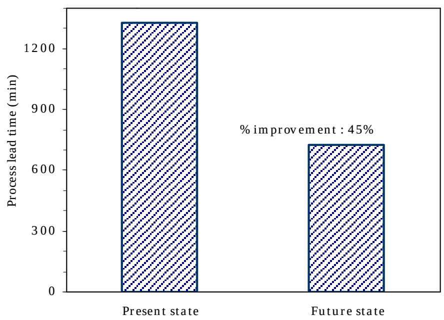

Figure 11. Reduction of process lead time

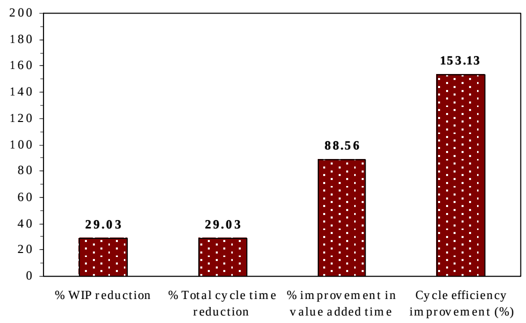

Figure 12. Improvement after lean approach

5. Conclusion

This present work provides a case study of the improvement of a construction equipment company non value added activities by means of lean tools. It focuses the revamp of operations by eliminating non value-added time and improving cycle efficiency through VSM. It can be concluded that VSM is an effective tool for identifying the processing wastes.

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