Internal Lead Time Reduction of Door Hinges through the Elimination of Mudas (Wastes) using Root Cause Analysis

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Abstract- The role of reducing internal lead time in a manufacturing facility is quite critical. The purpose of this paper is to determine whether reducing or eliminating mudas present in a system makes a difference and if it does, by how much. This is accomplished by implementing principles of lean manufacturing. A structured method of determining the origin of the problem in the system followed by root cause analysis of the problem and process study is followed. Finally, a method of improvement is suggested and its impact on the current system and the improvements is shown at the end. The wastes present in the internal supply line of door hinges were Motion and Transportation. Motion was due to unwanted double handling of the hinge bins by the workers at the flowrack which also caused immense physical fatigue. It was seen that by eliminating these wastes the internal lead time was brought down by 1120 sec from 1317 sec to 197 sec. The study showed that eliminating the wastes makes a huge difference in the lead time but also had a positive impact on the worker fatigue, i.e. drastically reducing fatigue.

Keywords –Lead Time Reduction, Lean Manufacturing, TPS, Mudas, The Seven Wastes, Root cause analysis

I. INTRODUCTION

The Toyota Production System (TPS) has been sought after by many companies, but none have been able to achieve the same success as that of Toyota itself. Toyota has been able to identify the various non value-added processes (Mudas) in their system and subject them to Kaizen (Continuous Improvement) for efficiency in the system. Internal lead time is the lead time of any component or material moving to reach a particular station or destination within the facility. This movement within the facility may involve many activities that happen to make sure that the component or material reach the right time and place. These activities are essential in order to fulfil the delivery to the respective work stations but sometimes these activities might be just non-value-added wastes which can be reduced or eliminated with improvements done in the internal supply line. These activities will not only add upon the lead time within the facility but also increase the physical stress caused due to excessive unwanted movements inducing fatigue to the workers in the facility while handling these components for delivery.

The TPS has been widely used interchangeably with the terms Lean Manufacturing and Lean Production. It is called Lean because, in the end, the process can run [1]:

- With less material
- Requiring less investment
- Using less inventory
- Consuming less space and
- With less people

L. Wilson [1] defined Kaizen as the concept of improving a process by a series of small continuous steps. These kaizen steps maybe small at a glance but when accumulated, these changes make a huge difference in the system.

The next section of the paper will deal with 7 types of mudas (wastes) that can creep up into a system. These are the wastes that have been reduced in the lead time reduction case study. This paper involves a case study of internal lead time reduction through the elimination of the mudas present in the internal logistics of door hinges required at the main line of an automobile manufacturer. The paper is structured in the following way. Section 2 gives a brief about the 7 wastes of lean manufacturing. Section 3 is the literature review undertaken followed by section 4 which is the case study. Section 5 gives the results and discussion and finally section 6 gives conclusion.

II.THE SEVEN MUDAS (WASTES)

Waste is anything that adds no value to a process or product. Reduction of waste is critical in TPS in order to achieve improvement. According to T. Ohno[2] wastes are of the following seven types:

A. Over Production

This is one of the main reasons which results in the other forms of wastes. Overproduction simply means manufacturing too much or too early, when it is not immediately needed. This is the most serious of all other wastes and needs to be dealt with severity. Over production leads to high levels of inventory build-up which may subsume other problems in the organisation.

B. Inventory

Inventory is the direct consequence of overproduction. Inventory costs the company money and resources to maintain them. Any material stuck as raw material, Work in process or finished goods inventory is a cost for the company until it is used for a subsequent process or sold to the customer.

C. Transportation

Transportation is simply the movement of materials from one place to another. This doesn't add any value to the final product. This movement of materials will need resources such as man power to move these materials either manually or by operated machines.

D. Waiting

If a product or a material is not being transported or processed waiting occurs. Waiting tends to disturb the flow of the processes, so must be dealt with much severity.

E. Over processing

Over processing occurs when the company uses inappropriate machines or methods for a particular process. Usage of expensive machines for a task that can be done with other inexpensive methods is an example of over processing. Inclusion of features into a product where the customer will not use those features is also another type of over processing.

F. Defects

Defect is one of the wastes that has a direct impact on the customer as well as the company. It is an obvious waste and has a cascading effect on other costs of the company such as reworks, scrap, increased inventories, etc.

G. Motion

This waste deals with ergonomics and health issues with respect to the workers and their job. All activities of walking, bending, reaching, lifting, etc. must be studied carefully as they cause stress to the workers and equipment, which leads to costing the company time and money. Jobs with such excessive activities must be analysed and carefully redesigned so as to decrease the strain on the workforce. This is one of the main muda eliminated in the case study.

III. LITERATURE REVIEW

Prior to the beginning of the undertaken project, a brief literature review was done by different personnel in different domains but related to the topic of this paper. Jaffar et al [3] conducted a study to measure the level of LMS implementation on management of seven waste in a participating automotive vendor. Of seven LMS wastes, it was found that the three most critical causes of downtime in the assembly line were waiting, transportation, and movement. The average percentage values for downtime frequencies for the three critical causes were 28%, 25%, and

12% respectively. The results indicated that the three major causes needed to be studied critically and understand their overbearing impact on the assembly process. Khalil A. El-Namrouty et al. [4] analyzed the current situation of a producing firm in Gaza Strip and the various activities involved in the assembly cost. The study aimed at implementing lean techniques by finding the seven wastes present in the system and completely eliminating them. Wastes Relations Matrix (WRM) was one of the tools used. The findings of the study concluded that many lean wastes were present which had an affect on the assembly cost of the product for the business organization in Gaza Strip, eliminating the wastes will reduce the assembly cost for the firm.

Yamashita [5] conducted a study of implementing lean manufacturing techniques at an organization in Minneapolis. After thorough understanding of the current system, lean was implemented which resulted in higher quality merchandise utilizing less resources and capital achieved by reducing scrap, rework, returns, and waste. He stressed on the importance of reducing the seven lean wastes in order to improve. S. Singh et al. [6] undertook a case study of a die casting industry. This case study shed light on the steps in implementation of lean, which engendered positive results within the industry. The implementation was based on 5 major lean wastes, which included defects, Inventory, Excessive material movement, delay due to waiting and over processing in the die casting. The recommended implementation was broken down into 3 phases. Phase 1 was a straightforward implementation which was less expensive for the company but would produce the needed positive effect on several different areas within the organization. Phase 2 included measures that were slightly harder to implement, involving higher costs of implementation, which would need higher managerial approvals. And Phase 3 included dedicated technical changes in machinery and tooling used in the manufacturing.

R. SuganthiniRekha et al. [7] undertook a study of an existing system in a production line of a steering gear box manufacturing industry and improved its productivity using lean techniques. A broad range of lean manufacturing tools were used for successful cost reduction of the components manufactured. The study revealed various lean wastes (mudas), which when reduced led to reduction in the total setup time by about 180 minutes and cycle time was condensed by about 98 minutes which ultimately reduced the lead time and increased the productivity. Kiran M et al. [8] made use root cause analysis and identify the problems within the system. A counter measure was given after careful planning which led to the increase in the productivity and availability of existing machines. Availability of machines was increased by reducing the downtime or breakdowns of the machines. The main objective of the paper was to analyze the production system and to ferret out the root cause of breakdowns which in turn caused production losses to the company and to suggest counter measures with which the breakdown can be reduced. A root cause analysis was conducted to find the source of breakdowns and areas of improvements were identified in order to reduce the downtime.

Branislav and Vesna [9] highlighted the major steps that should be taken for successful and permanent resolution of any problem from a problematic state. The paper had two major areas of interest – root cause analysis and corrective action process. The first area served the purpose of identifying the root cause which was the source of the issue and the second area related to the actions that needed to be taken in order to permanently eliminate the root cause thereby improving the overall system.

Through the brief literature review, it was understood that various lean manufacturing wastes could be present in a process or system and through the reduction or elimination of these wastes, continuous improvement of process or system can be achieved. This concept of continuous improvement was realized with the help of root cause analysis (RCA), wherein various lean wastes were uncovered which were present in the internal logistics of the door hinges needed at an automotive manufacturing company. Elimination of them led to the reduction of internal lead time of the door hinges. The proposed scheme is tested using ordinarily image processing. From the simulation of the experiment results, we can draw to the conclusion that this method is robust to many kinds of watermark images.

IV.INTERNAL LEAD TIME REDUCTION: A CASE STUDY

As discussed in the previous sections, reduction or elimination of the seven wastes is critical for the steady improvement of any process or system. In this section we will discuss and shed some light on how important it is to identify the non-value-added steps (mudas) and how steady reduction or elimination of these wastes will lead to a better overall system which is much more efficient and worker friendly. The following case study deals with the internal lead time reduction of door hinges required at the shell body main line of an automobile manufacturer. The Shell body Main line is the line wherein the outer shell of the vehicle is assembled along with the doors. The hinges are fitted at the hinge fitting station of the Main line. We shall understand that for improvement of the internal logistics of the door hinges, tackling of the wastes is important and where wastes are present, there is scope for improvement.

A. Methodology

To completely understand the problem and give a counter measure for improvement of system, we adhered to the following methodology. It was chosen as this is a case-based approach and relatively easier to implement in the case study. Figure 1 gives the overview of the methodology.

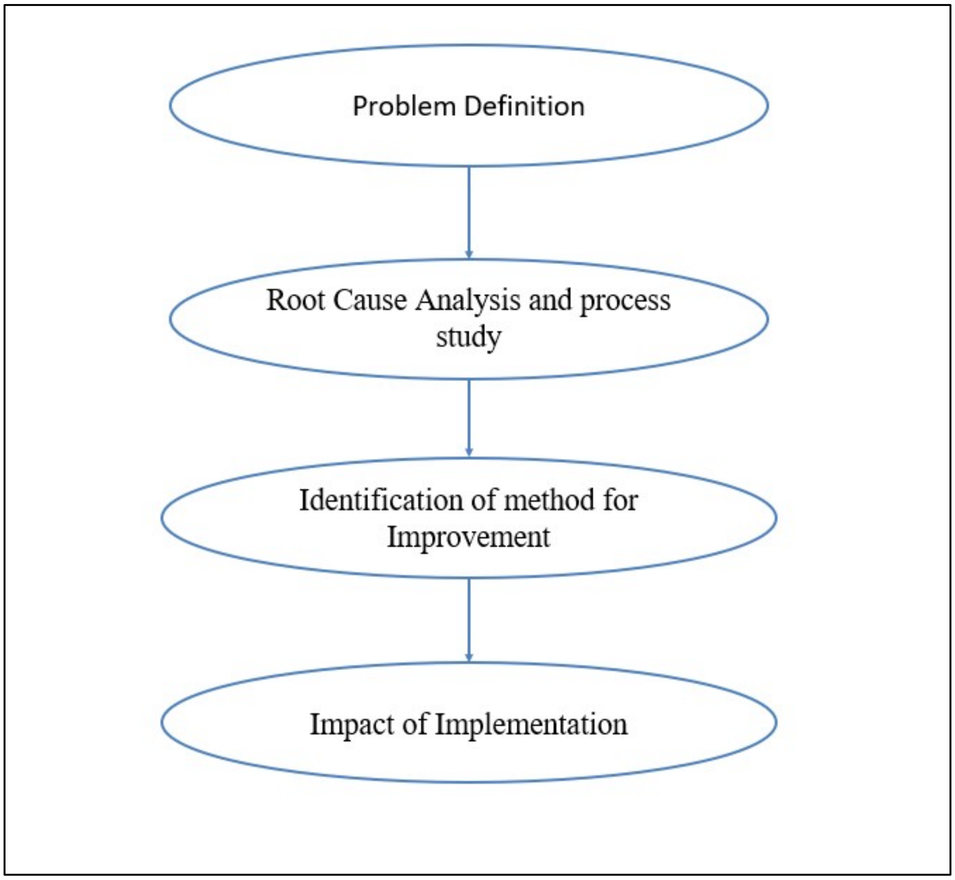

Figure 1: Methodology

- Problem Definition and Genesis

The problem was situated at the Shell body Main Line (SBML). There was an issue with the internal logistics of door hinges required at the hinge station of SBML leading to increased lead time of internal supply of hinges. Let us break down the problem. To do so, we have employed root cause analysis.

- Root Cause Analysis and Process Study

To understand why this problem was arising, we needed to understand the root cause of the problem. The component in study was the door hinges, so back tracking of the hinges supplied to the SBML was done. The door hinges were delivered to an intermediate storage (flowrack) located at the end of the Shell Body Sub Assembly (SBSA) by a tow motor from the stores (area where the hinges were being kept after receiving from supplier). SBSA is responsible for manufacturing of the sub-assemblies required at the SBML. The delivery of the door hinges was under the internal logistics department of the manufacturing plant. The hinges were reaching the SBML when one of the line operator from the SBML reaches the flowrack. He usually arrives at the flowrack pulling a dolly (trolley

used for movement of parts) containing empty hinges bins. He removes the empty bins from the dolly onto the flowrack and then loads the dolly with the filled hinge bins. He then takes it back to SBML using a tow motor since the dolly will is too heavy to be pulled manually. The hinges are taken to the right-hand side of the SBML from which the bins are equally split among the two sides of the main line, i.e. right-hand (RH) side and left-hand (LH) side of main line. The tow motor operator of logistics department would remove the empty hinge bins from the flowrack and take it back to the stores after repleting the flowrack with filled hinge bins. Each cycle, logistics would replenish the hinges at the flowrack. These hinges would come in bins of lot size ordered by the company.
The following are the list of activities involved in the internal hinge supply:

- Travel of logistics tow motor to flowrack
- Unloading of empty hinge bins from flowrack
- Loading filled hinge bins to flowrack
- Travel of SBML line operator to flowrack with empty bins
- Unloading of empty bins from dolly to flowrack
- Loading of filled hinge bins to the dolly
- Travel of filled hinge bins to SBML

The lead time of hinges encompass the above activities steering to a considerable amount of time.Time study of the activities was conducted for several cycles and an average of those times were taken and have been put in Table 1. The total breakdown of the timings is given in Table 1. It is clearly evident that the loading and unloading of bins at the flowrack by logistics and SBML line operator is double handling which is nothing but the waste of motion. Then there is the waste of transportation by line operator of SBML. This movement by the line operator of SBML from flowrack to SBML can be eliminated, which will be explained in the counter measure. Movement of logistics tow motor from stores to flowrack is essential for replenishment of the door hinges in the shop floor and cannot be taken as a waste. It is clearly evident that improvement in the lead time of hinges is possible if the wastes present in the internal logistics are reduced or if possible, completely eliminated.

SL No	Activity	Time(min) Approx.	Type of Muda
1	**Travel of logistics Tow motor to Flowrack**	**0.75**	**Nil (Essential Activity)**
2	**Loading of Filled Hinge bins to Flowrack**	**5**	**Motion**
3	**Unloading of empty hinge bins into tow motor**	**2**	**Motion**
4	**Travel of Line operator from SBML**	**1.1**	**Transportation**
5	**Unloading of Empty bins from Dolly to flowrack**	**2**	**Motion**
6	**Loading of filled hinge bins into dolly from flowrack**	**10**	**Motion**
7	**Travel Time to reach SBML**	**1.1**	**Transportation**
TOTAL TIME (sec) Approx.		**1317 sec**	

Table 1: List of Activities

As shown in the table 1, there is approx. of 1317 sec of work put in by the workers in order for the door hinges to reach the main line. These mudas can be reduced or completely eliminated so as to bring efficiency into the internal logistics of the hinges. Let us see how we can improve this.

- Identification of Method for Improvement

One way of dealing with this problem is by completely eliminating the intermediate flowrack present at the end of SBSA (Shell body Sub-Assembly). In the place of flowrack two dollies are introduced, one for right hand-side (RH) of SBML and one for left-hand (LH) of SBML. These dollies contain the hinge bins required for the respective sides of the main line. These dollies are delivered from the stores to the previously existing flowrack at the end of SBSA by the internal logistics department. In this way double handling of hinges by tow motor operator of logistics is eliminated. After the two dollies are in place, they are delivered to SBML by the sub-assembly's tow motor. It was observed during root cause analysis that two tow motors were delivering sub-assemblies (doors, hoods, back doors, etc.) that were required at the SBML. One tow motor for the LH side and one for the RH side of the SBML. Since the two hinge dollies are now conveniently placed at the end of the SBSA, the SBSA tow motors are made to take their respective hinge dollies to SBML. In this way a line operator from SBML was not required to leave his station and reach flowrack, unload and load hinge bins and finally take them back to SBML. This completely eliminated the travel time for line operator to reach flowrack (transportation waste) and the double handling (motion waste) during loading and unloading of bins at the flowrack. Reduction in these wastes brought down the lead time of door hinges to SBML drastically. The replenishment of the door hinges at the main line would now be done by the tow motor operators of the sub-assemblies. All that needs to be done now for the hinges to reach the main line is, the line operators of RH and LH side of the door hinge fitting has to inform their respective sub-assemblies tow motor operator to bring the door hinges along with its next supply to the SBML. This notification will be done when the hinges are nearing empty at the hinge station.

- Impact of Implementation of Solution

One impact of this counter measure was the elimination of the intermediate storage i.e. the flowrack. There was temporary buildup of hinge stagnation occurring at the flowrack when hinge was not being picked up by the SBML at the right time. Replacing the flowrack with the two dollies avoided this. This also freed up some space near the sub-assemblies. The second impact was the elimination of the motion waste which reduced stress on the body of the worker due to perpetual lifting and dropping of hinge bins onto the flowrack. Each bin weighed around 8 – 10 kgs. This was putting a huge strain on the worker's body, inducing physical fatigue. Double handling was reduced. This would no longer happen as the delivery of the hinges would be done by the tow motors of the shell body sub-

SL No	Activity	Time(min) Approx.	Type of Muda
1	**Travel of logistics Tow Motor for delivery of Hinge dolly to the location of the previously existing flowrack**	**0.75**	**Nil (Essential activity for delivery of hinges)**
2	**Setting of dollies in proper orientation**	**0.25**	**Nil (Essential activity for delivery of hinges)**
3	**Attaching of dollies with sub assembly dollies by sub-assembly tow motor operator**	**0.13**	**Nil (Essential activity for delivery of hinges)**
4	**Travel for delivering hinges to SBML**	**1.08**	**Nil (Essential activity for delivery of hinges)**
5	**Travel for bringing back empty hinge bin dolly**	**1.08**	**Nil (Essential activity)**
TOTAL TIME (sec) Approx.		**197 sec**	

Table 2: Revised List of Activities

assemblies (SBSA). The tow motors of SBSA had to just add in the hinge dolly along with their sub-assembly dollies and that would result in simultaneous delivery of both sub-assemblies and hinges to the main line. This would eliminate the transportation waste induced by the SBML line operator. Table 2 gives the breakdown of the activities occurring in the new system of hinge delivery.

V. RESULTS AND DISCUSSIONS

The logistics tow motor operator who used to load and unload the hinge bins at the flowrack would no longer require to do so and the only work he has to do is delivering of the hinge bin dolly to the appropriate place. Thus, with the solution implemented into the internal logistics of the hinges, the work put in by the workers to deliver the door hinges has been brought down to 197 sec. That is a decrease of 1120 seconds of work and internal lead time. Figure 2 gives an overview of the impact of implementation on the internal lead time.

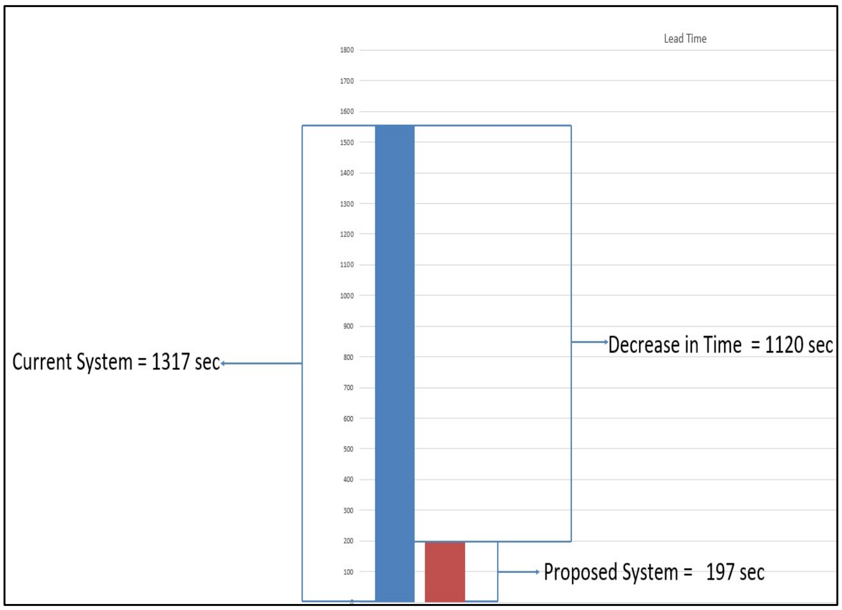

Figure 2: Changes in the Systems

VI.CONCLUSION

As mentioned, the internal lead time has been reduced by 1120 sec for the delivery of the door hinges to the mainline. By replacing the temporary storage with the movable dollies, workers can with ease deliver the door hinges to the mainline when compared to the old system. By implementing concepts of lean manufacturing and continuous improvement into the internal logistics, various mudas were identified and tackled with a counter measure. The counter measure provided did not require huge capital to implement and even though it was a small change in the system, it was effective nonetheless. The use of root cause analysis helped in the systematic identification of the root causes and tackling them appropriately. The internal logistics of the door hinges consisted of many mudas which gave rise to the high lead time along with non-value-added work done by the workers. Reducing or eliminating these wastes as explained in the case study can bring down the lead time and increase the efficiency of the supply system. This can also make it easier on the workers by reducing fatigue caused when involved in the delivery of the respective door hinges. This paper can be used as a starting point for other research work happening in the same field of lean manufacturing as well as improve upon by using much more sophisticated mechanisms.

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