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Application of Value Stream Mapping tool for waste reduction in manufacturing industry

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***Abstract*— Nowadays in a competitive market, all companies require small lead times, low costs and high customer service levels. As such, companies pay more effort to reduce the lead time. Started in the automotive industry, sequential improvement initiatives were implemented to enhance the manufacturing practice changes. As VSM involves in all of the process steps, both value added and non-value added, are analyzed and using VSM as a visual tool to help see the hidden waste and sources of waste. The present work addresses the implementation of lean manufacturing techniques through Value Stream Mapping tool in the wheel manufacturing system at an automotive manufacturing plant located in south India. Value Stream mapping aims at identification of waste in terms of non-value added activities. Current State Map is prepared to give details about the existing position and identify the bottlenecks in production line. Future State Map is made in next step to show the implementation action plan to improve the productivity or reduce the lead-time in the industry.**

***Index Terms*— Value Stream Mapping, Current state map, Future State map, LP- Light Passenger, D- Disc.**

I. INTRODUCTION

Due to a changing competitive environment, small and medium enterprises have to improve their production performance. A commonly applied philosophy to improve production performance is called Lean Thinking. This method, derived from the Toyota Production System, banishes wasteful activities while increasing the competitive strength and responsiveness of a company[1]. Many companies fail in their attempt to become lean and therefore techniques are needed to guide the implementation.

The need to provide customers with more value and at the same time reduce waste is a constant for any firm or organization. Those concepts form the basis for what is known as Lean thinking. Lean thinking is focused on creating a perfect process of value creation in product development and operations; along with the supporting processes within organizations. Based on the Toyota Production System, Womack and Jones identified five principles of lean thinking [2].

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. Value is specified by the customer.
. Value streams that produce each product can be identified and wasted steps challenged.
. Product should continuously flow through value creating steps.
. Product should be pulled through steps where flow isn't possible.
. Processes should be managed towards perfection to continuously reduce the time needed to serve the customer.

Implementing lean thinking often includes Value Stream Mapping(VSM), a process for linking together lean and quality improvement initiatives in order to give the greatest overall benefit to an organization[3]. In early quality initiatives, companies implemented programs to increase their overall competitiveness; however, improvements tended to be fairly localized. As these programs matured, quality initiatives moved from stressing the importance of quality and increasing inspection, to identifying root causes and solving problems upstream. Lean initiatives began to be used to reduce inventory, processing time and thus reduction in total production lead time[4].

Current work proposes to use Value Stream Mapping as an implementation technique or management tool for the waste reduction and productivity improvement in any organization. This technique is applied in an automotive wheels manufacturing industry in Light Passenger Vehicle(LPV) wheels division. First, one product family is selected. Then, the current state is described and data is gathered to understand each process step in more detail. Subsequently, a future state is proposed accompanied by a description of the most important improvements suggested, and an implementation plan is offered[5]. By applying the Value Stream Mapping tool to a specific division within this company, substantial improvement potential is revealed. Upon implementing the feasible suggestions after drafting the work plan through discussions with the management, remarkable improvements in production lead time, total cycle time and takt time can be observed.

1.1 Value Stream Mapping(VSM):

A Value Stream Map is an end-to-end collection of processes/activities that creates value for the customer i.e. what the customer is prepared to pay for. A value stream usually includes people, tools and technologies, physical facilities, communication channels and policies and procedures.

A value stream is all the actions-both value added and non-value added activities:

value added activities - Machining, Processing, Painting, Assembling

non-value added activities - Scrapping, Storing, Counting, Moving, Documentation etc., currently required to bring a product through the main flows essential to every product:

(a) the production flow from raw material into the hands of the customer, and
(b) the design flow from concept to launch.
Standard terminology, symbols, and improvement methods allows VSM to be used as a communication tool for both internal communication and sharing techniques and results with the larger lean community[6].

VSM is the process of visually mapping the flow of information and material as they are preparing a future state map with better methods and performance. It helps to visualize the station cycle times, inventory at each stage, manpower and information flow across the supply chain. VSM enables a company to 'see' the entire process in both its current and desired future state, which develop the road map that prioritizes the projects or tasks to bridge the gap between the current state and the future state. Based on the global review, it can be seen that VSM principles have been adopted across the world several years ago.

1.2 Processes in WIL LPV Production Line:
a) RIM Manufacturing process: strip cutting, marking & coiling, end flattening, butt welding, flash cutting, joint find clipping, edge conditioning, band oil dipping, coning, roll forming-1st,2nd & 3rd, expanding, valve hole depression & piercing, edge forming, deburr valve hole, leak test, visual inspection.
Low Carbon Steel(LCS) in the form of coils is used as raw material for rims. After the manufacturing process of rim, it is sent to assembly process by conveyor.
b) Disc Manufacturing process: blank and cup, reverse form, pierce bore, raise bore and flange down, bolt hole piercing and coining, multi-vent hole piercing and multi-vent hole coining.
Low Carbon Steel(LCS) in the form of coils is used as raw material for discs. After the manufacturing process of disc, it is sent to assembly process over conveyor.
Rims and discs with defects are sent to re-inspection or re-work area depending upon the severity of defects.
c) Rim & Disc Assembly process:
press disc into rim, MIG welding, calibration, buffing, visual inspection, runout check and polishing
The inspected and OK wheels are loaded on jigs of the over-head conveyor and are sent to paint plant for further processes.
d) Wheel Paint process: Cathodic Electrophoretic Dip (CED) Paint Plant -
The CED painted wheels are then sent by over-head conveyor for visual inspection process where the OK wheels are packed on pallets and are moved to warehouse area while the wheels with paint defects undergo paint touch-up process during the same inspection time before being packed. According to the customer demand and schedule, the wheels get shipped from time-to-time.
Certain specific wheels which require top coat paint like grey, red, pink, yellow etc., according to the customer requirement will be further sent to Top Coat Paint Plant after the CED inspection process through the over-head conveyor.

Ex: LP 1235 wheels require sapphire grey color as their top coat paint
Top Coat Paint Plant -
The Top Coat painted wheels are then sent by over-head conveyor for visual inspection process where the OK wheels are packed on pallets and are moved to warehouse area while the wheels with paint defects undergo paint touch-up process during the same inspection time before being packed. According to the customer demand and schedule, the wheels get shipped from time-to-time.

Below shown is the process sequence of wheel manufacturing in the company:
1. Raw material shipping
2. Rim manufacturing in LP1, LP2 & LP3 lines simultaneously
3. Disc manufacturing in D1 & D2 lines simultaneously
4. Rim & Disc assembly process in LP1, LP2 & LP3 lines simultaneously
5. Wheel paint -
   - CED paint
   - Top Coat paint
6. Inspection
7. Packing & Shipping

The production layout in the company is as given below:

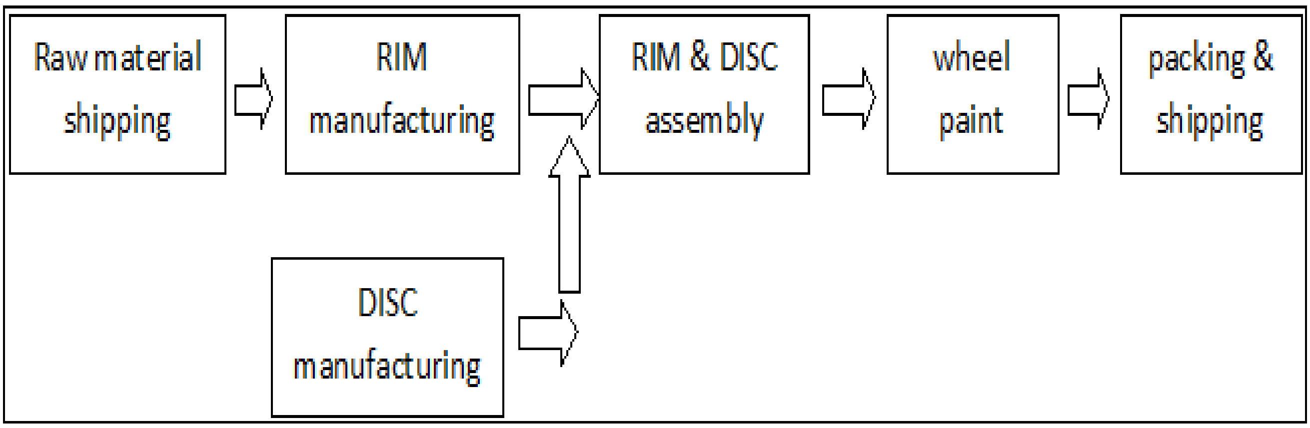

Fig.1 Production layout

II. LITERATURE REVIEW

2.1Lean-Manufacturing: Lean Manufacturing can be defined as "A systematic approach to identifying and eliminating waste through continuous improvement by flowing the product at the demand of the customer." Lean always focuses on identifying and eliminating waste and fully utilizing the activities that add value to the final product. From the customer point of view, value is equivalent to anything he is willing to pay for the product or service he receives. Formally value adding activities can be defined as: activities that transform materials and information into products and services the customer wants. On the other hand non-value adding activities can be defined as activities that consume resources, but do not directly contribute to product or service. This non-value adding activities are the waste in Lean Manufacturing. Waste can be generated due to poor layout, long setup times, incapable processes, poor maintenance practices, poor work methods, lack of training, large batches, ineffective production planning/scheduling [7].

2.1.1 Wastes in Lean Manufacturing:

The waste can be categorized into seven types which is commonly referred to as the “Seven wastes”. Taiichi Ohno suggests that these account for up to 95% of all costs in non – Lean Manufacturing environments. These wastes are:

a) Overproduction – Producing more than the customer demands. There are two types of overproduction [8]:

1. Quantitative – making more products than needed.
2. Early – making products before needed.

Overproduction is highly costly to a manufacturing plant because it obstructs the smooth flow of materials and degrades the quality and productivity. Overproduction manufacturing is referred to as “Just in Case” whereas Lean Manufacturing is referred to as “Just in Time”. The corresponding Lean principle is to manufacture based upon a pull system, or producing products just as customers order them. Anything produced beyond customer order ties up valuable labor and material resources that might otherwise be used to respond to customer demand. Ohno considered the fundamental waste to be overproduction, since it leads to other wastes such as overstaffing, storage, and transportation costs because of excess inventory.

b) Waiting – Whenever goods are not being moving or being processed, the waste, waiting occurs. This includes waiting for material, labor, information, equipment etc. Lean requires that all resources are provided on a just-in-time (JIT) basis – not too soon, not too late by linking processes together so that one feeds directly into the next and can dramatically reduce waiting[9].

c) Transportation or conveyance – Moving product between processes does not add value to the product.

d) Over processing or incorrect processing – Taking unneeded steps to process the parts. Some of the more common examples of this are reworking, inspecting, rechecking etc. This is due to poor layout, poor tools and poor product design, causing unnecessary motion and producing defects.

e) Excess Inventory – Any type of inventory (raw material or in process or finish goods) does not add value to the product and it should be eliminated or reduced.. Excess inventory results in longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay.

f) Defects – Defects can be either production defects or service errors.. Repairing of rework, replacement production and inspection means wasteful handling time, and effort[10].

g) Excess Motion – Any motion that employee has to perform which does not add value the product is an unnecessary or excess motion.

2.2 VSM Symbols:

In VSM various kinds of symbols are used to map the current state and future state. These symbols can be categorized as process, material, information and general symbols. Following figures describe the symbols used to draw the current and future state VSMs:

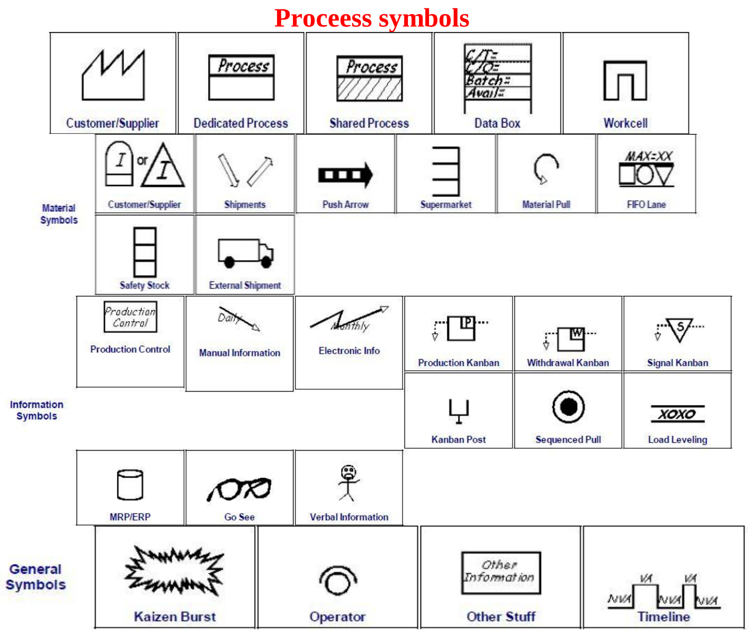

Fig.2 VSM symbols

III. OBJECTIVE

The average customer demand of Light Passenger Vehicle(LPV) wheels in the company since last 3 months (October, November and December) was found to be 2,00,000 units per month which had been a slight decrease in demand when compared to previous months. The trend continued in further months also and showed an impact on the sales and marketing. So in order to minimize the losses and get the maximum profit, the production cost per unit wheel should be brought down. One of the best methods to achieve it is application of Lean Manufacturing by lean principles. This can be achieved by eliminating the hidden wastes (non-value added activities) in production lines.

The various objectives of the current project are as follows:
1. Drawing the current state map of RIM and Disc Manufacturing lines,
2. Identifying the bottlenecks and scopes in the manufacturing lines,
3. Drawing the current state map of Paint Plant division,
4. Identifying the bottlenecks and scopes in the paint division,
5. Making the necessary suggestions for reduction of production lead time(NVA) and thus productivity improvement through future state mapping,
6. Making the work plan for implementation of future state map

The above objectives can be achieved by collecting the data through all the production lines and determining the data such as:
1. cycle time of each machine,
2. change over time of each machine,
3. uptime of each machine,
4. available time of each machine,
5. takt time,
6. output/day,
7. line efficiencies and
8. cost impact

After obtaining the data, the percentage change from current state to future state in cycle time and lead time has to be determined. Cost impact is one of the most important factors in the action plan of future state map because in order to minimize the losses and get the maximum profit, the feasibility and modification cost should be taken into consideration.

Though various suggestions are provided, only the feasible ones are taken into consideration by the company management depending upon many factors like demand of the product, production cost per unit, applicability of the change, need for the change, investment cost for implementing the change and necessary actions.

IV. METHODOLOGY

The procedure followed for VSM is as given below:

1. As variety of wheels get manufacture here in the company, initially a specific type of wheel in each particular production line should be selected for gathering the data. The selected wheels in different lines with their respective wheel codes are as follows:

- LP1 line - LP 1118
- LP2 line - LP 1257
- LP3 line - LP 1416
- D1 line - LP 1238
- D2 line - LP 1385

2. Note the product and process flow of each production line (LP1,2&3) indicating cycle time, change over time, uptime, availability of each machine in respective lines.

Ex: In LP1 line, the flow is-

i. Raw material shipping
ii. Rim manufacturing
iii. Disc manufacturing
iv. Assembly of Rim & Disc
v. Paint process
vi. Packing and Shipping

3. Note the individual cycle time of each processe in each line and calculate total cycle time of each production line - LP1,2&3

T.C.T = sum of individual cycle times of all processes in the line

4. Note and calculate the production lead time in each production line - LP1,2&3

P.L.T = sum of value added and non-value added activities = (cycle time) + (travel time+ queue time+ other NVA activities time)

5. Note the change over time, uptime of each machine and no. of available shifts for each line

• change over time = machine setting time **ex**: C/O of roll forming process in LP1 = 20 mins C/O of blank & cup process in D1 = 15 mins • uptime = (actual production time of a machine ÷ availability time) * 100 **ex**: U/T of roll forming process in LP1 = 90% U/T of blank & cup process in D1= 92%

LP 1:

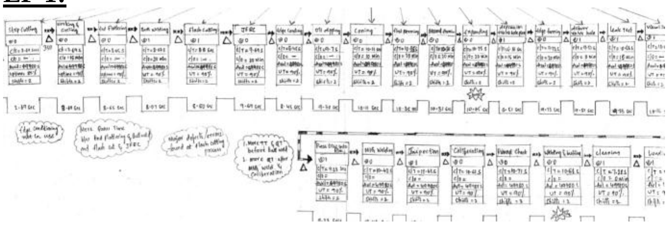

Fig.3 LP1 Current state

D1:

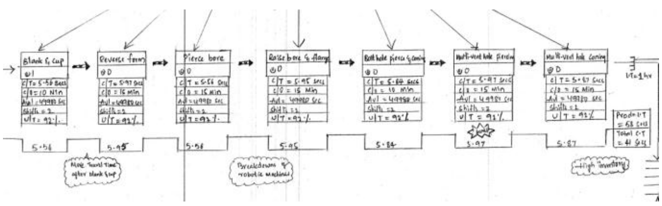

Fig.4 D1 Current state

Similarly draw the flow of LP 2, LP 3 and D2 lines

7. Calculate the takt time of each production line - LP1,2&3

takt time= (available time per day) ÷ (customer demand per day) • LP1 takt time = 9.06 secs/unit • LP2 takt time = 11.12 secs/unit • LP3 takt time = 11.12 secs/unit **ex**: In LP1, takt time= (6.8 hrs*3600) ÷ (2700 units) = 9.06 secs/unit

8. Identify the bottlenecks and scopes using the above collected data in all the lines such as:

- high inventories,
- more travelling and queue times,
- high production lead time,
- high total cycle time,
- machines having more break downs, failures, errors,
- poor layout etc.,

9. Draw the current state map of Rim manufacturing line and Disc manufacturing line separately indicating the defects and wastes with the corresponding suggestions. 10. Draw the current state map of Paint plant division same as above indicating the defects and wastes with the corresponding suggestions. 11. Finally, make the work plan for future state implementation.

CURRENT STATE MAP OF WHEEL RIM MANUFACTURING LINE

Fig. 5

CURRENT STATE MAP OF WHEEL DISC MANUFACTURING LINE

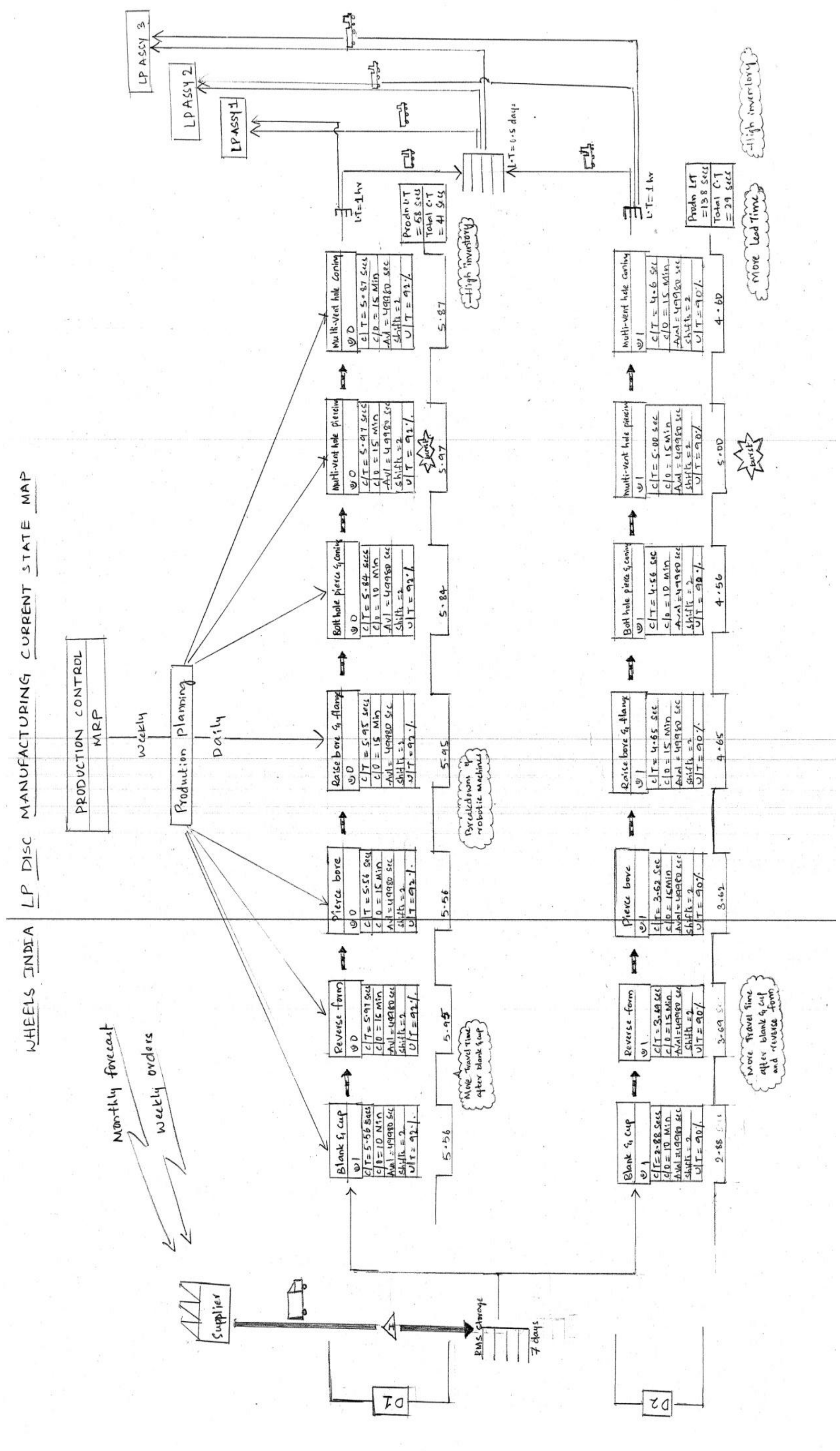

Fig. 6

CURRENT AND FUTURE STATE MAP OF WHEEL PAINT PLANT

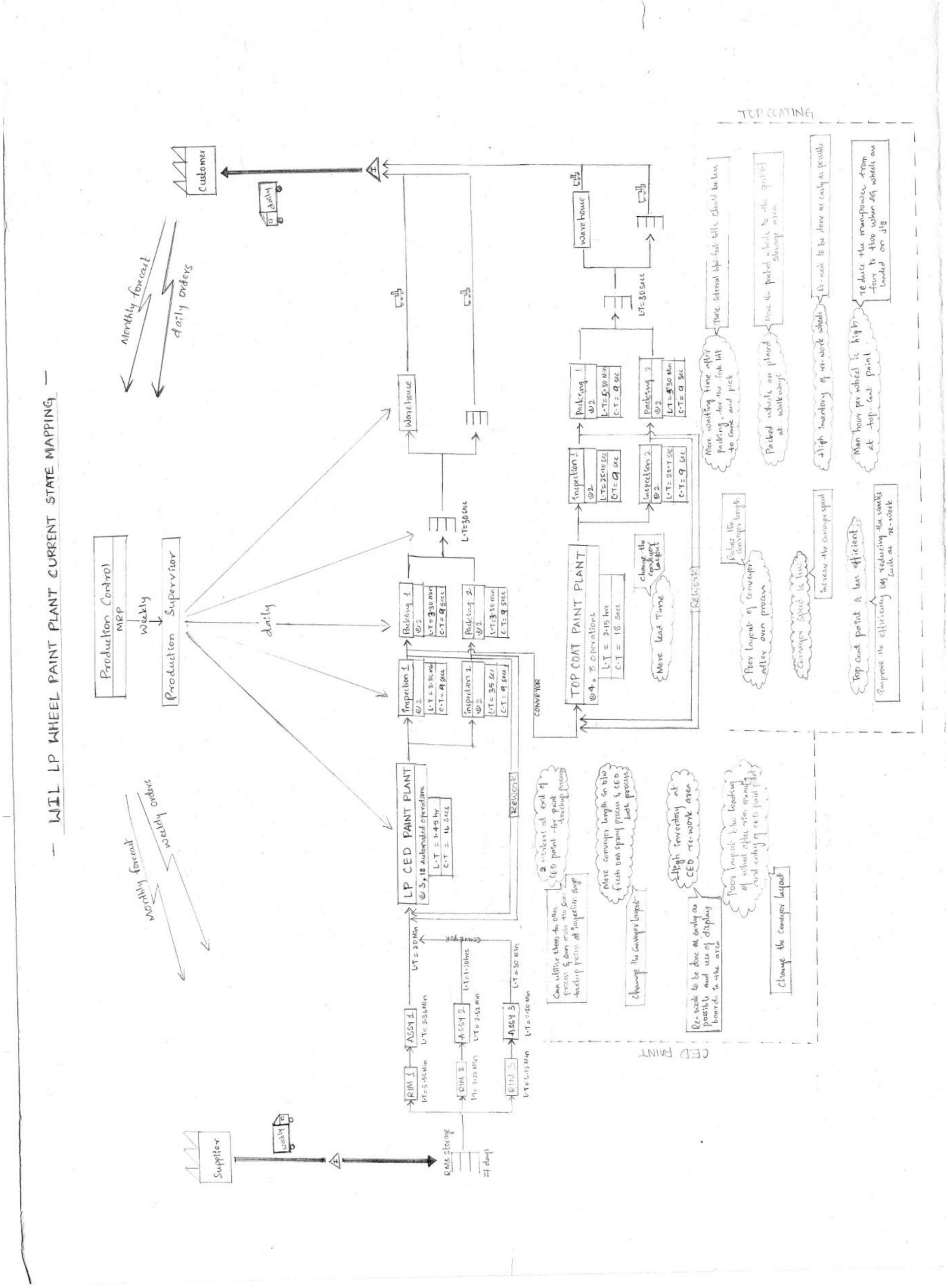

Fig. 7

V. RESULTS AND DISCUSSIONS

1. Among the 3 LP rim manufacturing lines, LP2 line has shown the highest production lead time(7.22 min) and total cycle time(194 secs)
2. Among the 3 LP assembly lines, LP2 line has shown the highest production lead time(2.52 min) and total cycle time(94 secs)
3. Between the 2 disc lines, D1 has shown higher total cycle time(41 secs) whereas D2(138 secs) has shown higher production lead time
4. LP1 line has lowest takt time(9.06 secs/unit) among all 3 LP lines
5. The top coat paint plant has higher production lead time(2.15 hr) and cycle time(18 secs) when compared to CED paint plant

The bottleneck (machine/process with highest cycle time) and scopes (chances or areas of improvements) in each production line including the paint plant division are mentioned below:

LP 1 (LP 1118)
bottleneck:
rim line - expanding (10.45 secs)
assembly line - buffing (10.61 secs)
scopes:
1. edge conditioning is not in use
2. more QT before butt welding process (avg. inventory= 3 wheels)
3. more QT & TT before JFRC process (avg. inventory= 3 wheels)
4. major defects/ errors found at flash cutting process
5. valve hole depression, piercing and deburring are manual
6. more QT & TT before PDIR process (avg. inventory= 5 wheels)

Line	Production Lead Time	Total Cycle Time
Rim 1	5.35 mins	152 secs
Assembly 1	2.36 mins	74 secs

Table 1. LP 1 line

LP 2 (LP 1257)
bottleneck:
rim line - first forming (12.52 secs)
assembly line - calibration (12.87 secs)
scopes:
1. edge conditioning is not in use
2. more QT & TT before butt welding process (avg. inventory= 6 wheels)
3. more TT before JFRC process (inventory = 3 wheels)
4. more production lead time for rim manufacturing and assembly lines
5. more total cycle time for rim manufacturing and assembly lines
6. valve hole depression, piercing and deburring are manual
7. more TT after calibration process (avg. inventory= 2 wheels)

Line	Production Lead Time	Total Cycle Time
Rim 2	7.22 mins	194 secs
Assembly 2	2.52 mins	94 secs

Table 2. LP 2 line

LP 3 (LP 1416)
bottleneck:
rim line - second forming (11.88 secs)
assembly line - MIG welding (12 secs)
scopes:
1. edge conditioning is not in use
2. second roll forming is being used though not required
3. more TT before JFRC process (inventory = 3 wheels)
4. Few breakdowns at automated valve hole depression and piercing and leak test
5. more QT and TT before PDIR process (avg. inventory= 5 wheels)

Line	Production Lead Time	Total Cycle Time
Rim 3	5.12 mins	207 secs
Assembly 3	2.30 mins	83 secs

Table 3. LP 3 line

Disc1 (LP 1238)
bottleneck:
multi-vent hole piercing (5.97 secs)
scopes:
1. more TT after blank & cup process
2. few breakdowns of automated machines
3. high inventory
4. more total cycle time

Line	Production Lead Time	Total Cycle Time
D1	58 secs	41 secs

Table 4. D1 line

Disc2 (LP 1385)
bottleneck: multi-vent hole piercing (5 secs)
scopes:
1. more TT after blank & cup process
2. more TT after reverse form process
3. more production lead time
4. high inventory
5. poor maintenance of machines

Line	Production Lead Time	Total Cycle Time
D2	138 secs	29 secs

Table 5. D2 line

CED Paint Plant
scopes:
1. poor layout of conveyor for wheel entry into CED paint plant
2. excess conveyor length before entering into CED bath
3. additional 2 workers presence at exit of plant for paint touchup process
4. high inventory of re-work wheels at CED inspection and re-work area

Production Lead Time	Cycle Time of each process(constant)
1.45 hrs	16 secs

Table 6. CED paint plant

Top Coat Paint Plant
scopes:
1. more lead time
3. low conveyor speed
4. less efficiency from top coat paint division
5. high man hour per wheel
6. more waiting time after packing for the fork-lift to come and pick
7. packed wheels are placed at walkways
8. high inventory of re-work wheels and OK wheels at re-work and inspection area

Production Lead Time	Cycle Time of each process(constant)
2.15 hrs	18 secs

Table 7. Top Coat paint plant

By following the proposed implementation path of the improvements, the performance of the production process can be improved. This will allow the company to cope with the fluctuations in demand with the same people using the same space.

VI. CONCLUSION

This paper illustrates the usage of Value Stream Mapping tool in an automotive wheel manufacturing industry to find out the bottlenecks and scope of improvements in the production lines by mapping the current state and future state. It was found that:

- In a particular month(Jan 2015), there was 5% re-work from the top coat paint division and the time spent to re-work it was 16.25 hrs (i.e, one working day)
- The efficiency of top coat paint plant is only 55%

It is concluded that LP2 and LP3 lines should be benchmarked with LP1 line, D2 with D1 line and Top Coat paint plant with CED paint plant.

The above stated data will have an impact on the cost/wheel because "Value" is what the customer is buying and it can be improvised by reducing the wastes in the production line through applying VSM effectively.

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