IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 04, Issue 09 (September. 2014), ||V4|| PP 22-31

Utilizing Value Stream Mapping for Scheduled Optimization of Heavy Duty Earth-moving Vehicles

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***Abstract*:** Growth of business world these days created higher market competition, because the existing industrial market become more global and have penetrated the inter-states boundary. In this global competitive scenario every company claimed to own the excellence and competitiveness so that, probability to win the competition is greater. Their ultimate goal is to satisfy the customer with the exact product, quantity, and quality in the shortest lead-time. It can only be achieve if the company is able to create and implement effective and efficient processes in each of its line of their business. For this, Lean tools are used to focus on the continuous improvement of a company towards reduction of various wastes like inventory, transportation, waiting, motion, cost factory space, correction etc. It is a systematic approach for eliminating waste in every area of business, including customer relations, product design, process layout, manufacturing sequence/operation and supplier networks. The system includes a wide range of tools and technique that aims at reducing inventory and production lead- time and to enhance the value added time and thus optimize the whole maintenance schedule. In this paper, an attempt has made to reduce the production lead- time (Dummy axle of heavy vehicles) of an automobile industry through value stream mapping. The result shows reduction in waste and system responsiveness according to the changing customers' needs through value stream mapping, a lean tool.

Key Words: *Kaizen, Kanban, Lean manufacturing, Lead time, Pull Production, Value Stream Mapping.*

Lean manufacturing is based on findings efficiencies and removing wasteful steps that don't add value to the end product. Lean Manufacturing is widely recognized as a mechanism for ensuring improvement in the manufacturing processes.
The goal of lean manufacturing is to reduce the wastes in terms of human effort, inventory, time to market and manufacturing space and become highly responsive to customer demand while producing world class quality products in most efficient and economic manner (Liker, 1998).(Todd 2000) and Shigeo Shingo (1992) strongly advocated the elimination of waste and put forth the idea, 'don't accept waste as unavoidable'. The basis of lean manufacturing is the elimination of waste.

1.1 Main Kinds of Waste in Lean Manufacturing:

(i) Over-production (ii) Defects (iii) Inventory (iv) Transportation (v) Waiting (vi) Motion (vii) Correction (viii) Over-processing (ix) Knowledge Disconnection.

II. LEAN TOOLS USED IN THIS STUDY

2.1 Kaizen- is a Japanese word for the philosophy that defines management's role in continuously encouraging and implementing small improvements involving everyone. It is the process of continuous improvement in small increments that make the process more efficient, effective, under control and adaptable.
2.2 Kanban- "Kanban" is a pull-based material replenishment system that uses visual signals, such as color-coded cards, to signal to upstream workstations when inputs are required by the downstream workstation.
2.3 Production Leveling - also known as production smoothing, aims to distribute production volumes and product mix evenly over time so as to minimize peaks and valleys in the workload.
2.4 Pull Production – In Pull system the production will flow from downstream to upstream as opposed to the traditional manufacturing concept. JIT is also about minimization of raw material, work in process and smooth flow of operations.
2.5 VSM- It provides various tools for data collection and analysis, in order to identify the waste occurring at different stages of manufacturing process and their impact on the overall production system. Minimization of the waste is the main objective of the lean philosophy. The role of value stream mapping is very important in the identification and subsequently reduction of waste. Value stream mapping is prescribed as part of the lean production portfoliooftoolsandhasbeenappliedinavarietyofindustries.VSM is useful in a situation like, product complexity (leading to differences in processing and set-up times across product variants),

parallel processing steps and/or different number of shifts used across a production line.

III. CASE STUDY OF A HEAVY DUTY EARTHMOVING VEHICLES (HDEMV)

The case study was conducted for HDEMV in an automobile industry located in eastern part of India which was a job shop industry. There were problems related with the wastes. In this study it was confined with two major parameters: manufacturing lead time and in-process inventory. The study was conducted keeping in view of the value stream mapping of a specific product line AB of dummy axle.

A dummy axle is located immediately in front of a drive axle and it is known as pusher axle**.** Material used in axle production is SAE Grade 41xx steel or SAE Grade 10xx steel, according to the product. SAE Grade 41xx steel has commonly known as chrome-molybdenum steel. SAE Grade 10xx steel is also known as Carbon steel.

In designed features of a dummy axle, the wheels on a lazy axle only come into contact with ground when the load is significant, thus saving unnecessary tyre wear. A dummy axle, also called dead axle, is not a part of driver train but is instead free floating. Many heavy weight vehicles use dead axles for strictly load-bearing purposes. Company is also producing trailer axles, LCV front axles, tractor axle and various other axles in this unit. It has a staggering capacity to manufacture 2, 00,000 axles/year. Axles are one of the most significant products Manufactured by the Company.

The monthly demand of axles is 7500 units. Time available per shift is different because break time is varying for every shift. Total number of shifts is three. Total time available for production is 1320 minute (3 shifts).

3.1 Problem Identification

In this industry two types of axle are manufacturing (i) Live axle (ii) dummy axle (dead axle).The industry was facing increased pressure both externally and internally, to improve the performance of a specific product line AB (dummy axle).These challenges are summarized in this table.

Table-1:

Externally focused challenges	Internally focused challenges
1. Increased no of suppliers for this product creating more choices for the customer. 2. Ability of competitors to meet customer requirements at a lower and better service. 3. Poor delivery performance and repeated missed delivery dates.	1. Lack of definition of standard AB product line. 2. Lack of clear and consistent process for scheduling and rescheduling work. 3. Discrepancy between quoted and actual lead times increases the pressure to reduce lead time.

3.2 Objective of the Paper

The main aim of this Paper is to develop strategies for elimination of operational inefficiencies and various wastes hidden in the Company by using lean manufacturing techniques like value stream mapping. In this Paper our aim is to reduce the Production lead time of dummy axle to meet the customer demand. The objective is to systematically demonstrate how lean manufacturing tools when used appropriately can help the industry to eliminate waste, have better product quality & better overall financial and operational procedures.

The expectations for improvement set for the (dummy axle) AB product line include:

1. Production of 270 axles/day, based on perceived market need (current production throughput is 247 axles/day) that means, to increase the production of AB product line without incurring additional capital expense.
2. Reduction in manufacturing lead-time from 60 minutes to 45 minutes.
3. Reduction in the in – process inventories and non-value added time.
4. To enhance the service quality and on – time delivery date.
5. To enhance the system responsiveness.

3.3 Background of Problem

Our aim is to offer a logically feasible and scientifically proven decision support system to select value stream mapping tools for detail analysis of waste while implementing lean manufacturing paradigm in an automobile company. Identification of the wastes having more negative impact on the organization and subsequently the selection of detailed value stream mapping tools are view a complex multi-criteria decision making problem.

3.4 Current State Map

Key features:

Help in visualizing the flows, Help identifying waste, Pull together the lean thinking principles, Help in deciding who should be in the implementation teams, Show relationships between information and physical flows and Create buy-in from the senior team undertaking the big picture mapping.

The company produces several products such as Axle, Propeller Shaft, motor, Transmission Components, Aluminum Castings etc. The focus of this value stream mapping is one product family, i.e. axle family. The customizations that occur inside a standard product family do not leads to significant differences in processing time and set-up time of other part families.

Cycle times of different processing steps for different axle family are shown in Table-2.

Table -2

Axle Family	**Axle Family (2515DA)**	**Axle Family (3118DA)**	**Axle Family (T. Axle)**
Processing stage	**A (Minute)**	**B (Minute)**	**C (Minute)**
Final inspection	8	8	8
Dressing and Deburring	6	7	6
Fab. Chamber, Bkt Weld	10	8	9
Machining 4	26	25	24
Z Bracket , Base plate & Assy.	5	4	5
Machining 3	7	8	8
Straightening	6	5	4
Painting	5	7	6
Shot blasting	6	5	5
SS, Flange assy. & weld	15	14	16
Lumps turning	8	9	9
Friction Welding	7	7	8
End Facing/milling	8	6	7
Machining 2	8	9	9
Machining 1	14	14	13
Shearing	5	5	7

3.5 Future state map

Based on the outcome of the current state map, defects, waiting time, and different inventory, are identified as the three major wastes affecting the performance of the industry under study. In this section, the wastes concerning with inventory, overproduction and waiting are taken into account. Analytical treatment is also included by taking into account takt time, pitch, Heijunka box etc. Improvements in the existing process have been identified and accordingly future state map has been developed.

The future state map is developed by answering eight questions in a straight forward manner, using approach prescribed by Rother and Shook (1999). Some questions must be answered for developing future state map. All these questions have different strategies and its applications.

Based on Rother and shook's approach the first five topics are related to basic issues for construction of future state map.

The next two topics deal with technical implementation details such as the detail of control system (heijunka box). They help in defining non-mapping details such as production mix, order release time, etc.

Finally, the last topic of the section is related to the definition of effort or actions needed (kaizen) to migrate from the current state to the future state.

3.5.1 Takt time

Takt Time = Available working time per day/Customer demand per day

Takt Time= (22 hrs. x 60 min//h) / 247 motors =

5.5 min/Axle (approx.)

3.5.2 Production finished goods supermarket

A supermarket is nothing more than a buffer area for storage of the products that are ready to be shipped and is located at the end of the production line.

3.5.3 Pull system supermarket

Sixteen additional pull system supermarkets are needed to create a continuous flow at complete dummy axle assembly depending on up- time, changeover time and percentage defects at different processing stages. Average cycle time (taking into consideration number of resources available) of different processing stages for different axle family are found. On the basis of average cycle time we calculate the average daily and monthly demand (42, 163, 42 for axle part family A, B, C respectively).

The next step is to calculate lot size, trigger point and number of kanban for different supermarkets.

3.5.4 Formulae for change-over, lot size & number of kanban:

di= Defect rate, Cri= average cycle time per piece

Dd = Daily demand of product in piece

T = Time available per shift X Number of shifts per day

Required run time for product in minutes,

Ri = (1+di/100) X Cri X Dd

Net available time for set-up and changeover,

Ts = T- ∑ Ri

Average Down time(Including set up and Changeover time)

= Total working hours X Down time

No of changeover per day= Total time available for changeover (Minutes)/ Average changeover time for every product.

Total run time per day= 440 minutes X 3=1320 minutes,

Required run time per day= average cycle time /day X average demand/day (for product A+B+C) =385 minutes;

Time available for change over = net available time – avg. d/t. =738 minutes (approx.);

Number of changeovers per day =time available for changeover / change over time= 82.034 = 82 changeovers per day. (Ref. Table No. 5)

Calculation of batch factor: Batch factor= Number of product family / Number of changeover per day = 0.037Setting up a lot size for production: By multiplying batch factor* demand / day(Lot size = Numbers of kanban) =3 pieces (0+3+0)

Establish a trigger point for reorder: Trigger point= Total lead time to replenish / takt time

By exercising all the four steps, we can determine the time available for changeover/cycle time per day, average lot size for production and trigger point for reorder of 16 pull system supermarkets in a whole value stream. Calculation of trigger point for reorder is only necessary for some supermarkets because changeover time is more &company needs a triangle kanban. In other supermarket changeover time are less, so calculation of trigger point for reorder is not necessary and simple withdrawal kanbans are used.

Inventory levels at various supermarkets **:** By proceeding the same way in all the supermarkets we can calculate required run time / day, time required / day, to meet average demand, net time available for set-ups and change-over, average down time, desired number of change-over / day ,batch factors, lot size and number of kanban or ,inventory levels at various supermarkets.

Tables No5.0 provides details of lot size, number of Kanbans, total lead-time, takt time, and trigger point for reorder to the supermarkets ahead of every processing stage and is calculated on the basis of aforementioned equations. Similarly, we can calculate lot size, number of Kanbans, total lead- time, takt time, and trigger point for reorder from one supermarket to the other supermarket.

3.5.5 Continuous flow

Whenever the supermarkets are at their full capacity then the respective processing stage switched to make other product types. To stop overproduction at any workstation in the value stream, only one processing stage in the supplier to customer value stream needs to be scheduled. The processing stage is called the pacemaker process, because this point sets the pace of production for all the upstream process together.

3.5.6 Production at the pacemaker process / Production leveling

The basis for addressing Pacemaker process is to distribute the production of the three axes part families uniformly over the production line at the pace maker process. To determine the production sequence, level the product mix in a given pitch interval and produce the three different products at constant rate.
The relationship used is:

$q_{ir} = (r-0.5)\ (Q / D_{di})$

Here Q= Total no of product demand in one day
Ddi = Demand quantity of A, B, C product
r = 1, 2, 3………n

Table-3 Production sequence for smooth production

Product(i)	Unit(r)	q_{ir}	q_{ir}(Sorted)	Product(i) Sorted
A	**1**	**2.940**	**0.757**	**B**
A	**2**	**8.821**	**2.273**	**B**
A	**3**	**14.702**	**2.940**	**A**
A	**4**	**20.33**	**2.940**	**C**
A	**5**	**26.46**	**3.788**	**B**
A	**6**	**32.34**	**5.303**	**B**
A	**7**	**38.226**	**6.8190**	**B**
A	**8**	**44.107**	**8.821**	**A**

3.5.7 Pitch for pacemaker process

Depending upon the sequence determined by the production leveling, one should release and withdraw (the "pitch") the increment of production from the pacemaker process? The pitch is the basic time unit of the production schedule for a axle family.

Table-4 Number of pitches for every product

Product	Time interval per pitch
A	1305/42 = 31 Minute
B	1305/54 = 24 Minute
C	1305/42 = 31 minute

3.5.8 Process Improvements:

To realize future state map, it is essential for the company to incorporate improvements in the material and information flow as envisioned after intensive analysis of various processes. Whatever is the value of takt time, pitch, kanban control and production leveling etc. discussed in the steps to formulate future state map, it may not lead to the improvements in production unless specific efforts are directed to improve the processes by involving specific set of lean tools.

Lot size, trigger point and no of kanban for supermarket between z bracket, base plate weld & Machining 4.

Table No 5

Part	Average demand per day (pieces)	Average Cycle time per piece (min)	Average change-over time (min)	Average scrap rate	Down time	Required run time per day (min)
A	42	1.625	9	7%	15%	68.25
B	163	1.5625	9	7%	15%	254.687
C	42	1.500	9	7%	15%	63.00
						385.937
Net time available for setup and change over (min.)						934.063
Average down time (not including setup and changeover) min.						195.75
Time available for change over (min.)						738.313
Desired number of changeover per day						82.034
Batch Factor = number of parts/ desired no of changeovers per day						0.036

Products	Lot size	No. of Kanban (Containers)	Total Lead Time(min)
A	2	2	18

B	6	6	25
C	2	2	18
First container time	=	3 minutes	

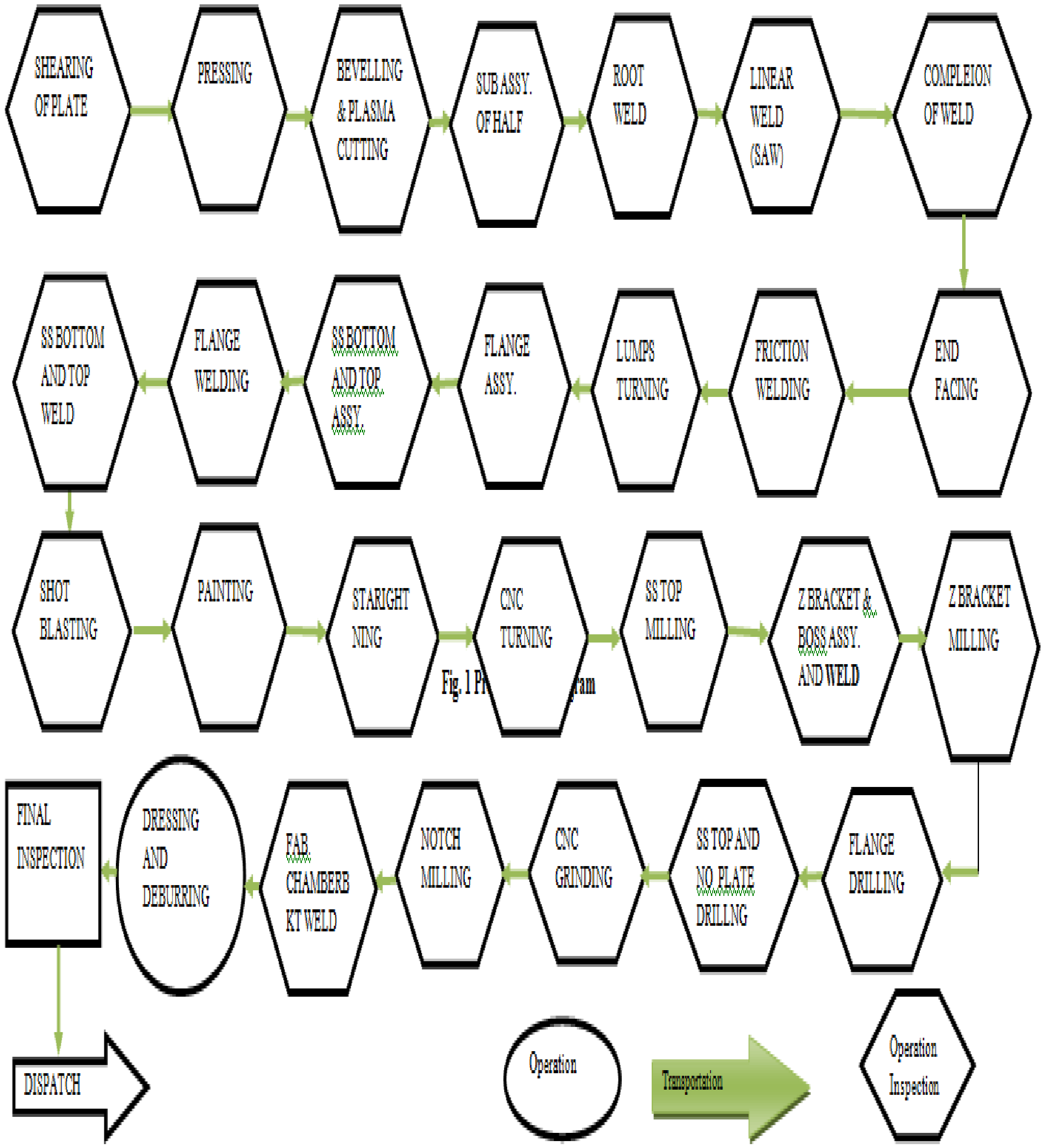

Fig. 1 Product flow diagram of HDEMV Part

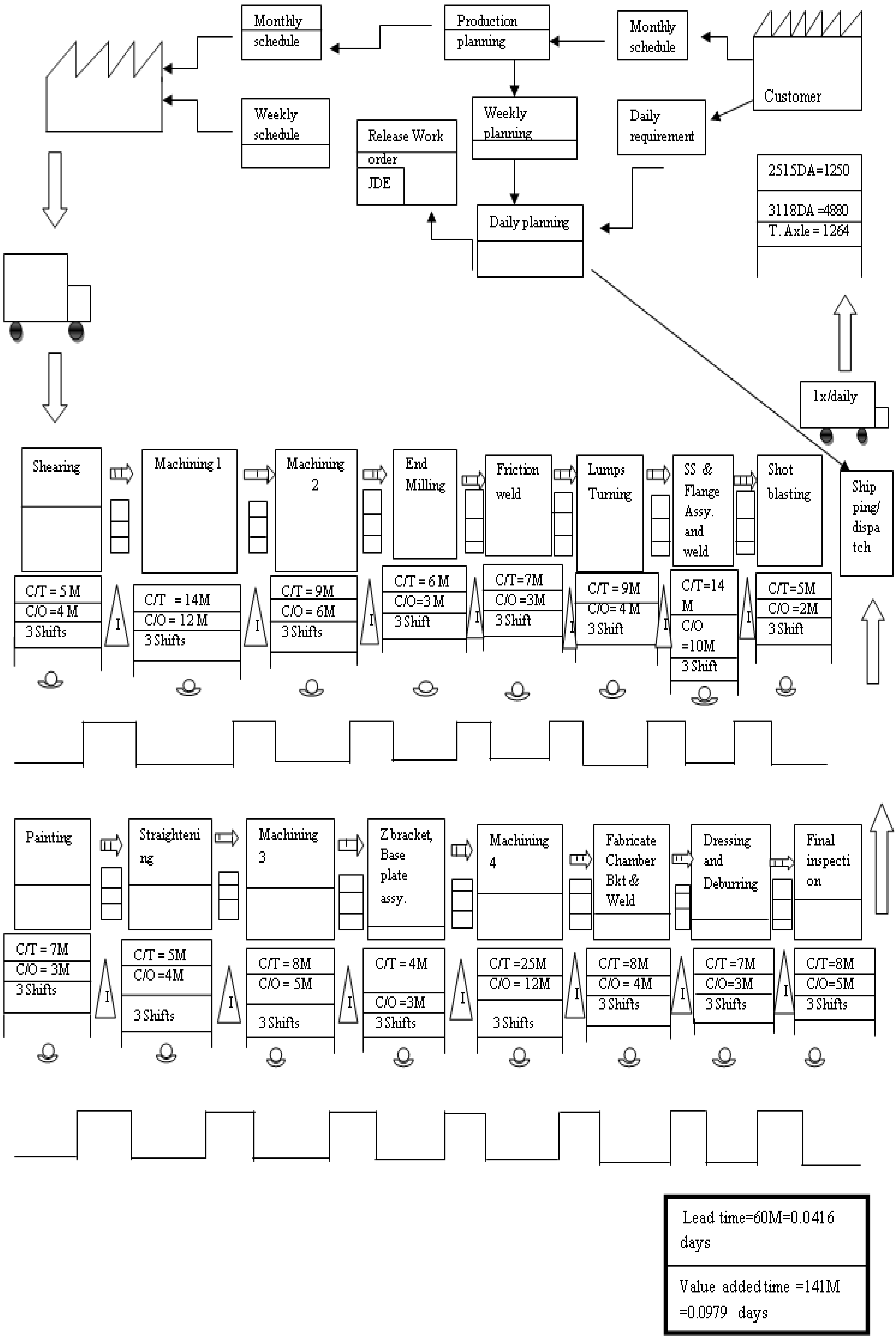

Fig. 2 Current State Map for Process Scheduling

Machining1 contains these processes (i) Pressing of half (ii) Beveling and Plasma Cutting (iii) Sub assembly of half
Machining 2 contains (i) Root weld (ii) Linear Weld (iii) Filler weld
Assembly & weld contains (i) flange assembly and No punching (ii) SS bottom and top assembly (iii) Flange welding(iv) SS bottom and top weld
Machining 3 contains (i) CNC turning (ii) SS top milling
Machining 4 contains (i) Z bracket milling (ii) Flange Drilling (iii) SS top drilling (iv) CNC grinding (v) Notch Milling & plate drilling

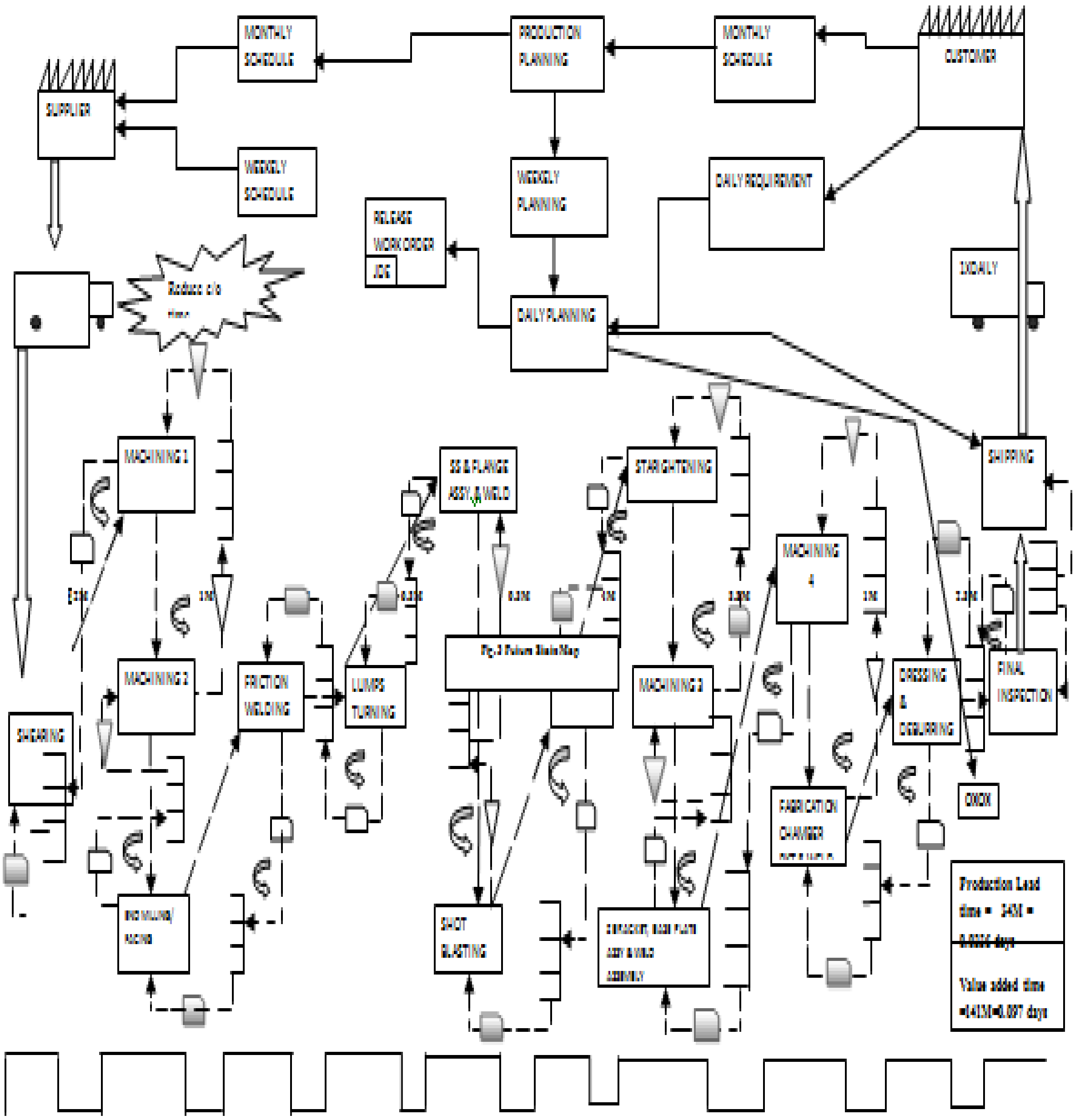

Fig. 3 Future State Map for Scheduled Optimization

IV. RESULTS & DISCUSSION OF CASE STUDY

Three wastes identified as vital wastes after analysis i.e. inventory, overproduction and waiting. These wastes must been addressed through value stream mapping (developed in the future state map). The axle manufacturing company must adapt to a change to have a flexible production system. Sixteen pull system super markets have suggested at different stages. The lot size and the number of kanban requirements at each super market are calculated. Triangular kanbans are utilized for replenishment of three super markets which are located after the processing stage (Machining1, SS Flange assembly & Weld and Machining 4) having higher set up time and requiring higher inventory level.

This means that only when the inventory level reaches the trigger point, a triangular kanban will be send to the succeeding stage to produce the whole lot of the product according to the lot size. The same cycle keeps on repeating for different products within a day according to the production sequence (**B-B-A-C-B**) and number of pitches per day. The whole production system runs on the principle of pull system of manufacturing and the products are manufactured only when they are required by the application of pull system, a drastic reduction in the in-process inventory, and elimination of waste related to over production is anticipated. The inventory lead-time falls from 60minutes to 34minutes. Therefore, reduction of in-process inventory by 43% has estimated by implementation of the future state map.

4.1 Future scope:

Future studies should integrate the approach with economic measures to express both value-added and non-value-added costs sustained through the process. The primary goal is to develop simulation model for balance throughput, WIP and production lead-time and also integrate simulation model through value stream mapping. Simulation makes not only testing ideas easier, cheaper and quicker, but also gives immediate assessment of proposed changes to the system. Different objectives, such as cost minimization, machine availability maximization, should explore to examine the performance of the simulation model. Secondly, a more substantiate simulation model should be constructed to incorporate more practical issues by relaxing some assumptions. Simulation models have to be developed by observing the actual processing times of activities in the process and then characterizing their variation by statistical distributions.

V. CONCLUSION

The main aim of this paper is to develop the various strategies to minimize the wastes that existed in the AB product line in form of operational in-efficiencies, in process inventory and manufacturing lead-time. It has observed that wastes occur in different layer at different processing stages and to overcome this, continuous improvement is necessary, this will not only lead to waste minimization but also enable the company to survive and prosper in a competitive environment of continuous and unpredictable change. Value stream mapping (VSM) has proven not only to be universal but also to be universally successful at improving results. When applied appropriately for scheduled optimization, VSM is a well- understood and well-tested technique upon which simulation models has to be build.

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