Implementation of Lean Techniques in links Manufacturing Industry to Reduce Production Lead Time

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Abstract: *In their activities, manufacturing sectors are always facing cost-reduction and efficiency challenges. In order to survive, manufacturers require improvements in their production Lead Times, costs and levels of customer service. Because of this, companies are keen on loyal customers. So, more effort was made by companies to improve their efficiency.*

In this paper Value Stream Mapping (VSM) is one of the powerful lean tools used in LINKS manufacturing industry by focusing on process and cycle times for a product LNK413. This is used in construction and forestry mobile equipment. Value stream mapping will helps us to make visible the overall flow of material and information of an entire process. In order to use value stream mapping, it includes five steps data collection and identifying the customer needs, creating the current state, analyzing the current state and proposing the future state. Current state mapping shows the areas for improvement and different wastes in the process. From the current state map, it was noticeable that cutting and welding operations are bottlenecks in the entire process for LNK413. This has waiting time 3.5 and 4days because of break downs and minor stops. That leads to poor Overall equipment efficiency and longer manufacturing lead times.

Lean concepts and methods are applied or recommended for the reduction of the recognized waste (over production, waiting time, movement, defects). The future State map has been presented and the production lead time from 24.63 to 18.71 days has been reduced.

Keywords: *Lean techniques, Value stream mapping, Wastes, OEE (Overall equipment efficiency), Manufacturing lead time, Total productive maintenance (TPM).*

I. INTRODUCTION

The rapid changing environment of the competitive market in this 21st century, industries requires new operation atmosphere that are more efficient and leaner. Consequently; new ways, new methods and new management techniques have got the spotlight and strong realization by organization according to time, value, quality and customers. Those factors are already got attention by industries especially manufacturing industries for long term strategic objective and also involved into their daily operational activities in production floor. The traditional concept of customer satisfaction and greater organizational efficiency in this century has determined high quality, short production lead times, higher use of the resources and competitiveness of prices.Among these deterministic factors, 'time' has been getting high priority and other factors have been strongly correlated with time. In generally if the manufacturer takes long time to deliver product to its customer, then the associate cost ofmanufacturing will increase and vice versa. Managing this 'time' which is called lead time; has been acquiring more focus in this fierce economy. The traditional operation manager tried to keep the product cost lower by economical batch production management and lead time was usually long in the last century. But later on, the changing nature of business make customer to demand short lead time. To adapt the business competition, organizations, producers and manufacturers have been seeking the technique to reduce the lead time. In addition, organizations finds that 90-95% percent activities in a manufacturing lead time are non-value added activities for which customers doesn't want to pay. The effort of human creativity discovers that there are different types of wastes such overproduction; defects, reworks, excess motion, waiting time etc that consumes time and makes the production lead time longer. By analyzing and eliminating those non-value added activities and wastes from processes manufacturing lead time could be reduce significantly and an optimized result could be recognized.

Company and Process Background

UNI manufactures three point linkages, straight pins, tapered pins, links for construction and forestry mobile vehicles like Cranes, Tractors, JCB's, Trucks etc. It locates at Visakhapatnam, Andhra Pradesh, India. It has some familiar customers like Volvo, Cat, Yanmar (German), Kubota (German). This paper mainly focuses on a product family (LINKS).

At UNI the business department receives demand from different automobile companies. UNI have repeated customers. Where the demand is received on a 3 months basis. The company will ship the goods on monthly basis. Customers communicate their requirements for every 3 months through call or E-mail. Since these are committed customers the quantity and order delivery times are more or less fixed. When an order arrives both the business department and planning enter into planning system, estimate the date by which they can complete it. A rough schedule is prepared and sent to the production department on weekly basis. After that they will fix a routing on the order and assign a plan for month to it. Rough schedule on the operating side become the basis to supervise the day by day and week by week increments against how closely they are in accord with the schedule. The schedule can be updated further based on the requirements. It can be daily or bi-daily schedule.

UNI uses three types of transport modes: roadway, water way, airway. It mostly prefers ships to transport for various countries like Germany, Canada etc. In rare cases it prefer air ways only the customer needs the product in emergency. The shipments go to different customers on the daily and weekly basis.

The plant works on a continuous basis for 24 hours a day all year long except for major shutdowns and runs 3 shifts per day each shift is 8 hours long in all production department. Except cold drawingthis runs 2 shifts per day each shift is 12 hours long.

Manufacturing Process

The main objective is to focus on a product LNK413. After the order received, procurement department will procure the required raw material and store it in the raw material warehouse. The process for this product starts with the shot blasting. The raw material is loaded on to the conveyor. It feeds the raw material in to shot blasting machine. Metal steel balls are impinged on to rounds in order to clean the surface of raw material. Next operation is cold drawing to reduce the diameter of the raw material (i.e. From ϕ66 to ϕ64) thus different activities; Cutting, Turning, Drilling, Induction hardening, Grinding, Welding, plating, inspecting and packing are performed to convert semi-finished goods into finished goods. The finished goods are finally stored in finished goods warehouse and then shipped to the customer.

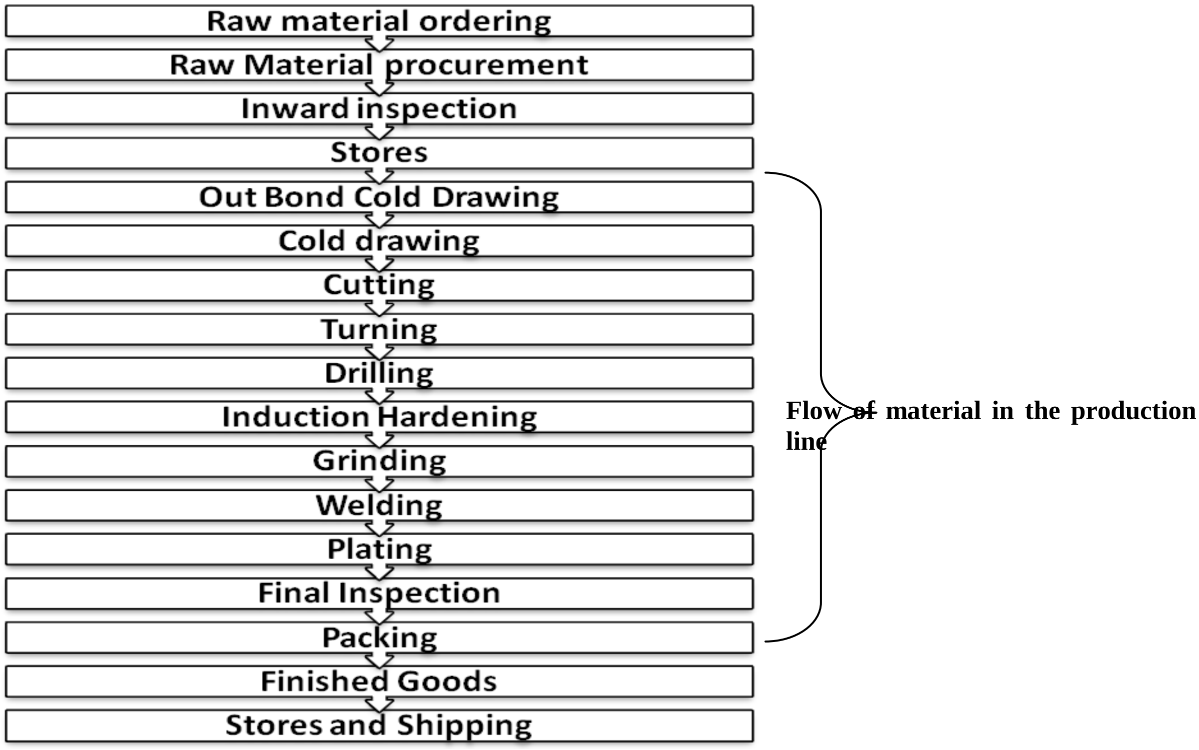


Fig 1: Flow of material for LINK'S in industry

II. LITERATURE SURVEY

VSM acts as one of enterprise improvement tool in Lean manufacturing helps to identify and analyse the current state of a product and propose a future state focused on reducing waste, improving lead-time[1]. VSM provides outline for implementing lean techniques by illustrating how the flow of material and information should operate.

K. P. Paranitharan (2012) research provides use full platform for implementing lean tools in manufacturing industry to reduce production lead time, Inventory and improve in productivity by modifying layout and balancing to TAKT time

R.M.Belokar (2014) details a case study application of VSM in automobile industry where he achieved 67% improvement in cycle time by improving VA activities.

G.Sahitya Reddy (2013) identified VA activities and NVA activities in the process. Later he implemented Lean manufacturing techniques to reduce NVA activities. Result in reduction of manufacturing lead time.

Naka Jima (2002) is credited with the fundamental TPM (total productive maintenance) which is a major departure as of that 'you operate, I maintain' philosophy.

Prabhuswamy (2008) felt that (TQM) and (TPM) systems implementing simultaneously will help to improve operational and excellence in product quality. It involves operational and maintenance staff to work together as a team to reduce wastage, minimize down times and improve end productive quality.

According to Peter Wilmot and Walter man (1982) TPM is a system of maintaining and improving the integrity of production system, through the machine, equipment, process and employees that add value.

In this paper, an attempt has been made to discuss implementation of lean principles using value stream mapping and Total productive maintenance to reduce manufacturing lead time, waiting time, improve productivity, quality and overall equipment efficiency. In links manufacturing unit,Located near Visakhapatnam, Andhra Pradesh, India. UNI manufactures four different categories of products. Out of which, we focused on only one product LNK413.

III. RESEARCH METHODOLOGY

Step 1: Theoretical construction of the thesis:
Step 2: Preparation of questionnaires and database sheet based on primary observation:
Step 3: Data collection and analysis:
Step 4: Problem findings and suggest improvement scope.

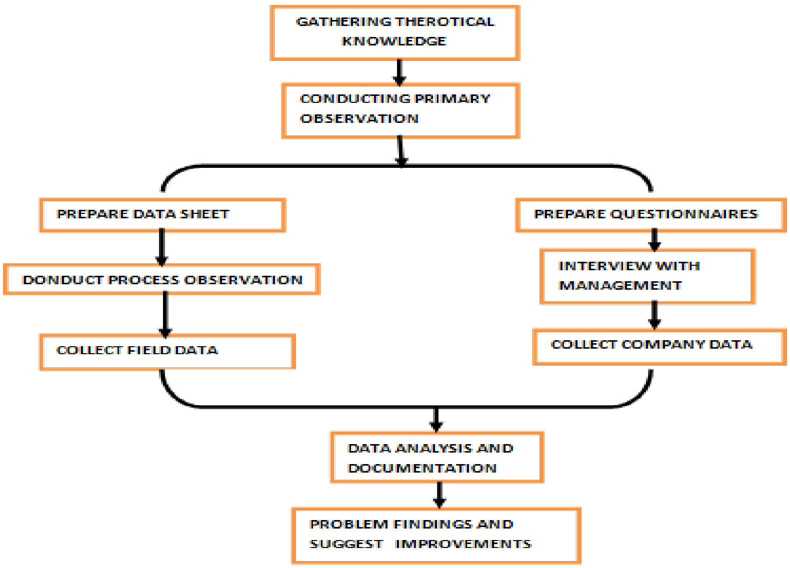


Fig 2: Flow diagram for research and methodology

IV. VALUE STREAM MAPPING

Value stream mapping formally defined as "All the steps both VA and NVA activities required to receive a product or service from raw material to the waiting arms of the customer". It is a lean tool helps us to see and understand the flow of material and information as a product makes its way through value stream. Mapping means simple just follow a product in their production path from customer to supplier, and carefully draw a visual representation of every process in the material and information flow. The waste that lies in the process is easily identified, brainstorm the reasons behind that and propose a future state.

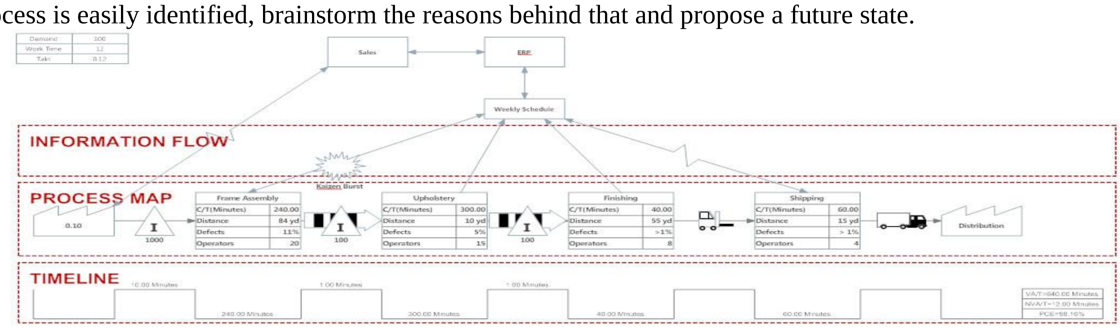
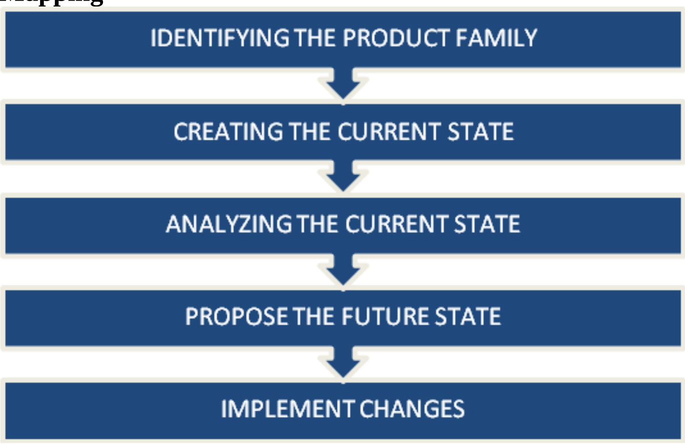


Fig 3: Information and material flow

The biggest problem for UNI daily operations was long lead times. In order to develop these times, the team lay up several project goals. One of the main goals of my project was to create a future state VSM that illustrated the idyllic material and information flow for UNI. With the creation and implementation of VSM, UNI's current manufacturing lead time should be reduced by 25%.

Steps in Value Stream Mapping



Identifying the Product Family

A product family is a group of products that go by similar processing steps and over familiar equipment in downstream process. UNI produces different kinds of products like 3-point linkages, straight pins, tapered pins and Links. Before starting it we need to focus on one product family. Customer thinks about their particular product, not all the products. We cannot map everything that goes in shop floor. Unless we have a small, one-product plant, drawing all product flows on one map is too complicated.

To determine the product family. I created a matrix with "processing steps and equipment on one axis and different products on another axis". From fig 4 the blue colour products comes under one product family and red colour comes under the other product family because these products share 80% of process steps.

SELECTING A PART FAMILY																	
	operations																
PARTS		COLD DRAWING	CUTTING	TURNING	FACING	DRILLING	CHAMFERING	TAPPING	STAMPING	INDUCTION HARDENING	TEMPERING	OD GRINDING	WELDING	BUFFING	ALKALINE Zn8-13/C with Cr3+	HYDROGEN De Embritt.ER(180)-4	TOP COAT SEALANT
	LNK413	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
	LNK415	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
	LNK256	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
	LNK217	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
	LNK325	√	√	√	√		√		√	√	√	√	√	√	√	√	
	LNK284	√	√	√	√		√		√	√	√	√	√	√	√	√	
	SPN206	√	√	√	√	√	√		√	√	√	√			√	√	√
	SPN363	√	√	√	√	√	√	√	√	√	√	√			√	√	√
	TPN021	√	√	√	√	√	√		√	√	√	√			√	√	√

PRODUCT FAMILY

Fig 4: the product families

So, from the Fig straight pins have 336 hours, tapered pins having 360 hours and links having 528 hours manufacturing lead time. These manufacturing lead times are gathered based on the previous data. 3-point linkages manufacturing lead time is 480 hours but assembling of three point linkages will takes place in another plant which is located in Noida. In this project I choose the product family LINK because they are having longer manufacturing lead times compare to the other products.

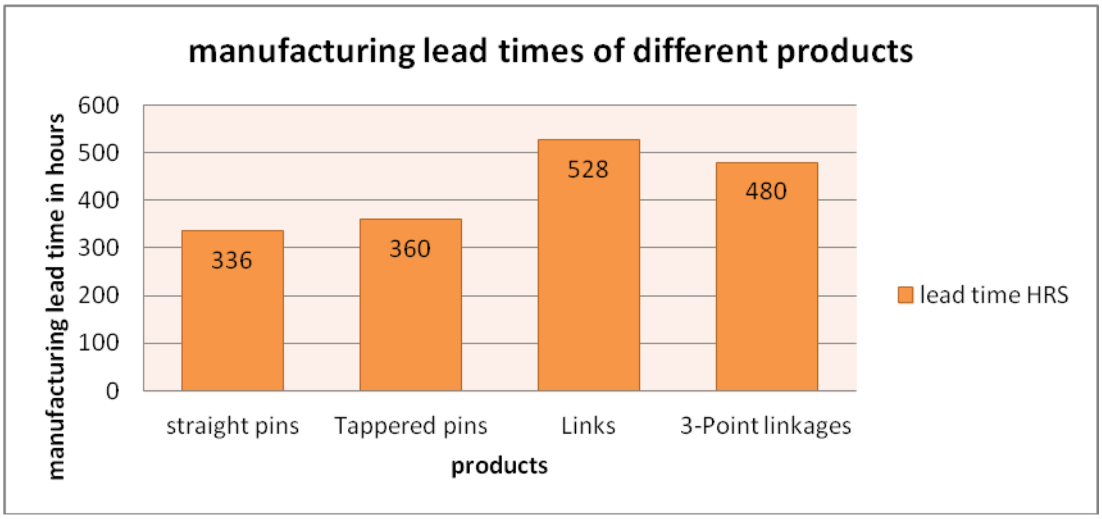


Fig 5: Different products and their manufacturing lead times.

Creating the Current State

The first step in accomplishing current state map by physically walking along the value stream of a product LNK413 from door to door, i.e. Gemba walks. The first walk along the value stream is performed to get a primary understanding about the Sequence of processes and what job it is who perform the process. The first walk initiates the building of an basic map .The first map is constituting the backbone of the process, containing external actors and operations, but only the flow not process data.

The next phase is to start gathering of the necessary data as possible, i.e. in addition to what was already discovered during the start-up phase. Since interviews are an essential method of gathering data, several interviews were therefore conducted. See table 1 for list of interviewed persons

Table 1: List of Interviewed Persons in UNI

List of Interviewed persons
1.Business Manager
2.Planning Manager
3.Supplying Unit Manager
4.Shipping and Receiving Manager
5.Finishing department Manager
6.Production HOD
7.Logistic and Purchasing Manager
8.Machine Operators in PMP unit
9.Welders
10.Operators in Shipping and Finishing Department

The interviews were based on similar types of questions at every operation. Key questions to the interview have involved what are your responsibilities? How do you know what to do and when do to it? Where is the required material coming from as well as going to when finished? By asking these types of questions a relatively inclusive representation of the current state was provided. Data about the work processes and different work cycles were received. It was also possible to puzzle the answers together and get an overall view of the whole material flow within the factory. Besides this, the interviews have been both formal in terms of actual meetings in an office environment and informal, e.g. with operators in the production. A lot of emphasize have been put on talking to the persons on the shop-floor, to make sure that the information would be as close to reality as possible.

Obtained Data

Customer Requirements

- Customer :ABC
- 1600 pieces per week.
- Corrugated-box packing with up to 88 pieces in a box.

Work Time

- 6 days in week
- 3 shift operation in all production departments.
- 8 hours every shift.
- Manual processes stop during breaks.

Process Information

1. **SHOT BLASTING:** Rounds are loaded on the conveyor which passes through shot blasting machine in order to remove rust on the round. • Semi-automatic process with 1 operator. • Cycle time: 1:52 min • Changeover time: Ø	2. **POINTING:** The round of length 5800 mm and diameter Ø66mm is placed into the pointing machine to reduce the diameter Ø64mm up to the length 200mm. • Manuel process with 1 operator. • Cycle time: 0:47 min. • Changeover time: 25 min.
3. **COLD DRAWING:** The round of Ø66mm is reduced to Ø64mm • Semi-automatic process with 1 operator. • Cycle time: 1:00 min. • Changeover time: 35 min. • Observed inventory: 2.42 days	**4. CUTTING: (HORIZONTAL BAND SAW)** • Semi-automatic process with 1 operator. • Cycle time: 1:35 min. • Changeover time: 30 min. • Observed inventory: 3.5 days After cutting , material waited for 2.62 days in between the process due to more WIP at Turning≥facing≥drilling≥chamf≥stamping.
5. **TURNING –FACING-DRILLING-CHAMFERING-STAMPING:** This all operations are by one machine. • Automatic process with one operator for two machines. • Cycle time: 5:10 min. • Changeover time: 90 min. • Observed inventory: 4.22 days	**6. FACING-TURNING:** Automatic process with one operator for two machines. Cycle time: 3:30 min. Changeover time: 60 min. Observed inventory: 1.34 Days
7. INDUCTION HARDENING: • Automatic process with one operator for two machines. • Cycle time: 1:30 min. • Changeover time: 90 min.	**8. TEMPERING:** • Automatic process with one operator for three machines. • Cycle time: 0:19 min. • Changeover time: Ø. • Observed inventory:0.68 days
9. TAPPING: • Manuel process with one operator for one machine. • Cycle time: 1:00 min. • Changeover time: Ø. • Observed inventory: 0.63 days	**10. OD GRNDING:** • Manuel process with two operators for one machine. • Cycle time: 2:13 min. • Changeover time: 60min. • Observed inventory:1.12 days
11. ROBO WELDING: • Semi-automatic process with one operators for one machine. • Cycle time: 2:00min. • Changeover time: 120 min. • Observed inventory: 4 days	**12. BUFFING:** • Manuel process with two operators one for buffing and other for chipping. • Cycle time: 3:50min. • Changeover time: 5:00 min.
13. ALKALINE Zn-13/C with Cr3+: • Automatic process with 4 operators twofor loading and two for unloading. • Cycle time: 0:30min. • Changeover time: 40 min.	**14. HYDROGEN DE EMBITTERS:** • Automatic process with one operator for machine. • Cycle time: 0:30min.
15. FINAL INSPECTION AND PACKING: • Manuel process with 4 operators. 2 for inspection and 2 for packing. • Cycle time: 2:10min. • Changeover time: 20 min. • Observed inventory: 0.60 days	**16. SHIPPING DEPARTMENT:** • Loads the finished goods in to trucks and deliver the shipments to the customer through water ways.

Last phase is to draw the current state map with obtained data. When creating a Value Stream Map (VSM), it is generally recommended to do by hand. Before illustration the map, it is recommended to draw on a large piece of paper and that you arrange it down horizontally, or in 'landscape mode'. This is because to fit all the process steps on the same line, and the map tends to be more wide than tall.

The next step in fulfilling the VSM is to add information regarding how material andinformation flows within the value stream. We are going to map the product family start with diagramming the material flow therefore we will start at end of value stream and the customer received his product. Collect the data of current situation to look at the material flow. This may require several walks along the value stream. Subsequently, relevant and useful process data is added to the map. However, since the analysis is not performed, abundant process data may be added. There is no common model for value stream mapping, but there are some frequently used symbols that offer a good starting point when learning the method. These are listed in Fig 6 below.

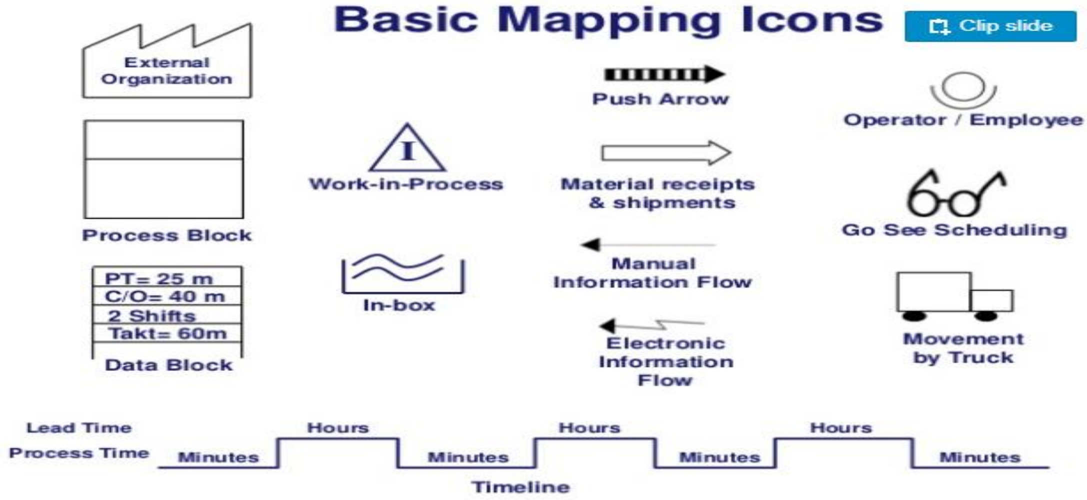


Fig 6: Basic symbols in value stream mapping

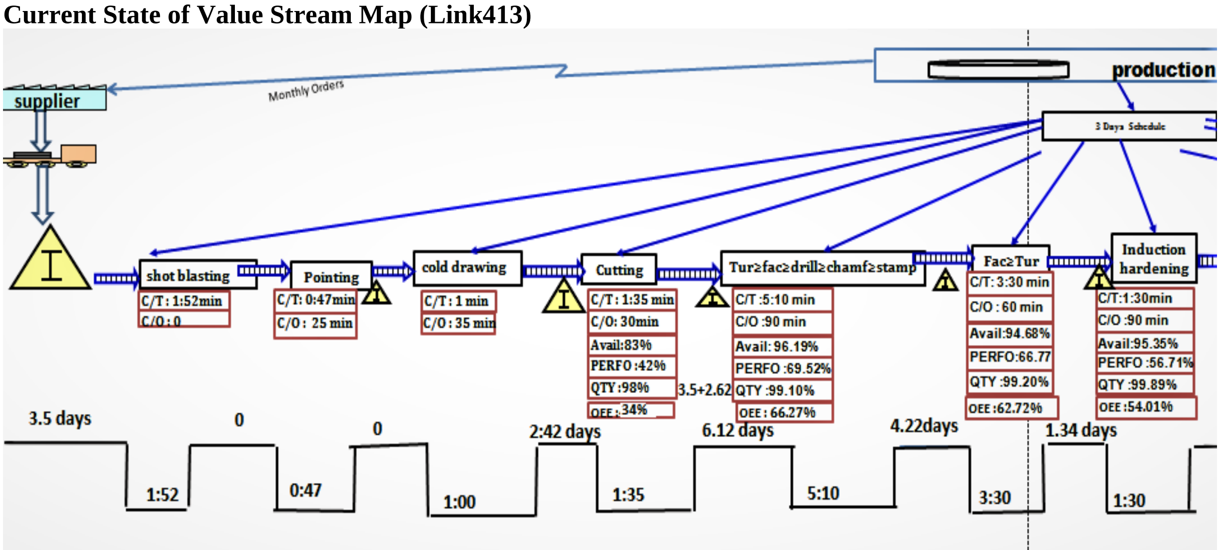
We should understand which icons to use. Every value stream has some basic samples.

Supplier and customer are the external sources. Then they are some specific symbols for material flow. Here in this below Fig 7: we see the process box "Shot blasting, pointing, see other 14 process boxes". Below this process box we see the data box which includes "cycle time, change over time, percentage of machine availability, performance, quality and overall equipment efficiency". Normally the data we collect over here is related to the organization problem we want to solve. We see inventory it is the time that parts are products are waiting during the process. The thick arrows between process box indicates the push system or push arrow where material is pushed to downstream of the process. The thick arrow from shipping to the customer indicates the movement of shipment. Beside the movement is done by the truck, we could also use pictures such as plane or ship.

There are other symbols used in information flow. The thin arrow indicates the information flow this linked to the central production control process. The arrows shaped like flash light, indicate the electronic information flow. Most of the time the information for the external parties will be electronic. The straight thin arrow indicates manually information flow.

Extra information is given from production control department to every process based on the 3 days schedule.

Current State of Value Stream Map (Link413)



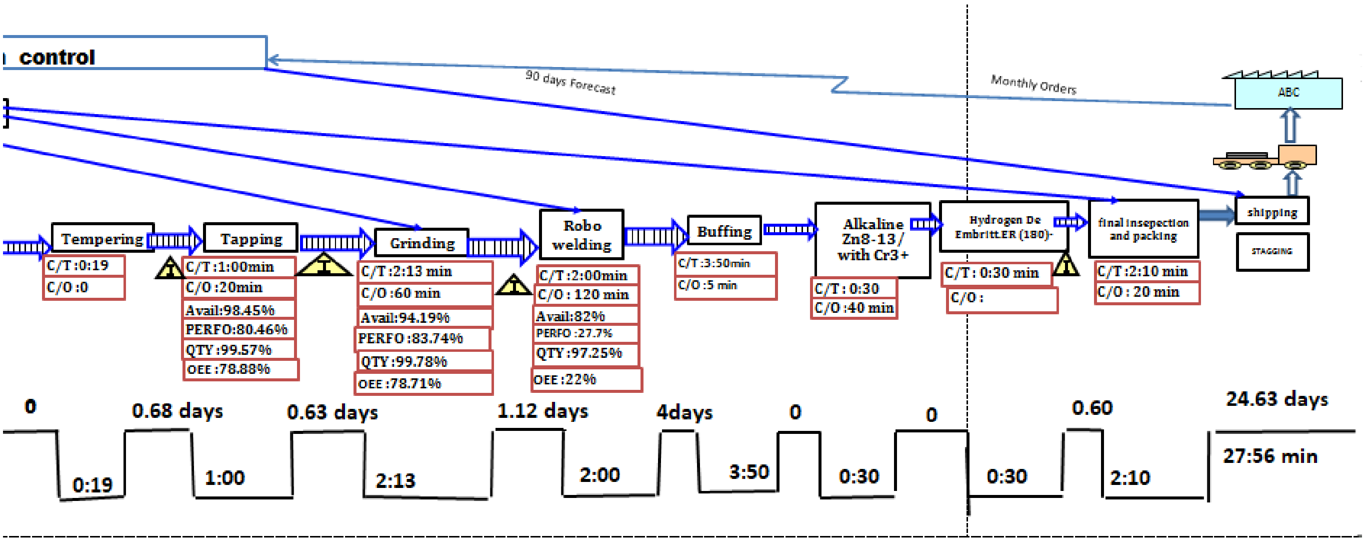


Fig 7: current state value stream map

Analysing the Current State

After drawing material and information flow we need to perform some analysis activities. First of all we should analyse what the value added and non-value added time. We can find this information in the time line box. Here from the current state of value stream mapping we can see the production (manufacturing) lead time is 24.63 days and value added time 27:56 min. The elements that add non value to the product are called waste. These wastes only add cost and time. So, this is what we should get rid of. In order to find the causes of waste root cause analysis was performed. There after we can use lean principles in future state by eliminating the waste in current state.

❖ *Metal Cutting*

Horizontal band saw machine (semi-automatic) is used to cut the rounds into required length. Here the process doesn't really run according to the plan because the maximum output that can be achieved per day on one machine without any break downs is 814 nos, it's impossible to achieve the theoretical output (814 nos) Because of losses. But the actual output on one machine is 287 nos per day. We can conclude that the average output per day is very low. That leads the production lead time to 3.5 days for 1003 nos. the identified waste at this operation is waiting time it is because of break downs and minor stops.

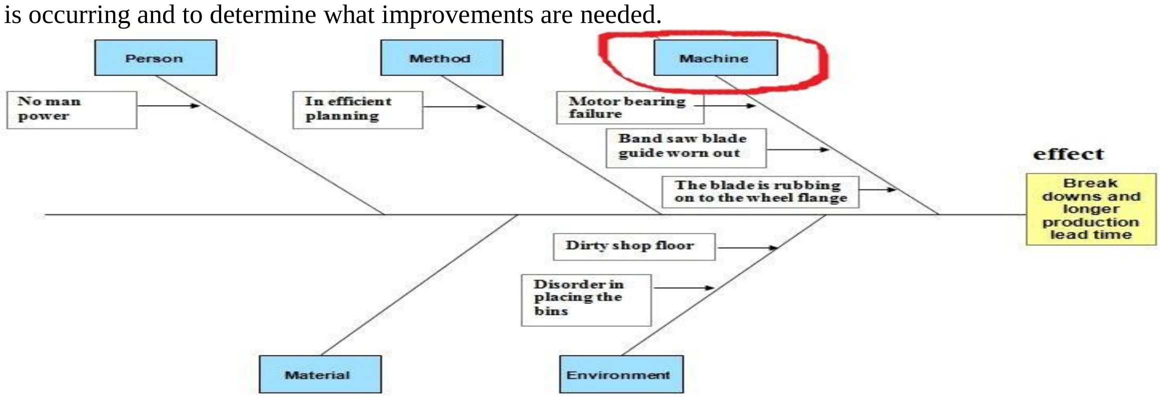
Work centre description	Total utilized hours	Total non-utilized hours
Metal cutting(Horizontal band saw)	62.75	12.5

Number of parts produced	Processing time in min	Number of parts rejected	Percentage of rejection
1003	1.58	**14**	**1.4%**

The production lead time is 3.5 days(84 hours) for 1003 nos. The total utilized time is 62.75 hours and total non-utilized time is 12.5 hours. The remaining 8.75 hours is planned breaks (tea breaks, lunch break etc.)

➢ *Root Cause Analysis*

Metal cutting operation has waste in the form of machine downtime (non utilized time) due to breakdowns that leads to unscheduled maintenance. The time and resources spent on fixing the problem. Many times we may think that the issue is solved but in reality we have just addressed a symptom of the issue and not the real root cause. In the metal cutting operation, root cause analysis is conducted to identify breakdowns, why it is occurring and to determine what improvements are needed.



➢ *Problems Observes*

Table no 2: problems observed at cutting operation

PROBLEM	**CAUSE**	**REMEDY**	**AVERAGE TIME TO REPAIR (Hrs)**
Blade breakage	The blade is rubbing on to the wheel flange	Check the wheel alignment and ensure diameter is correct	2.5
Noisy pump	Motor bearing failure	Change the bearing	3
Cut is not vertical	Band saw blade guide worn out	Replace	4
Machine stopped	No manpower	Allot manpower	3
		Total	**12.5**

➢ OEE of Metal Cutting Operation
Total planed production time = 75.25 hours.
Down time = 12.5 hours.
Actual cycle time = 1.58 min.
Actual production time = Total planed production time - Down time =75.25-12.5= 62.75hour.
Total quantity produced = 1003 nos.
Good quality = total quantity- rejected quantity = 1003 – 14 = 989 nos.

- **Machine Availability** = $\frac{totaltime - downtime}{totaltime} \times 100$

  $= \frac{75.25 - 12.5}{75.25} \times 100$ = 83%

- **Performance** = $\frac{Actualcycletime \times numberofpartsproduced}{autualproductiontime(min)} \times 100$

  $= \frac{1.58 \times 1003}{62.75 \times 60} \times 100$ = 42%

- **Quality** = $\frac{goodquality}{totalquantity} \times 100$

  $= \frac{1003 - 14}{1003} \times 100$ = 98%

- **OEE** = ***machine availability*** × ***performance*** × ***quality***

- **OEE** = 0.83 $\times 0.42 \times 0.98$=0.341

OEE = **34%**

❖ *Welding*

Robot welding machine (semi-automatic) is used to weld the links. Welding is an operation where the skilled worker is required to fix the part into the fixture and to operate the machine (robot welding machine).Here the worker requires some knowledge to identify the defects that are occurring during process. so, that he can stop the process to identify the problem and rectify the problem immediately. In UNI they are facing more quality problems (perpendicularity, blow holes, weld bead position) because of welding. The maximum output that can be achieved per day on one machine without any break downs is 645 nos, it's impossible to achieve the theoretical output (645 nos) Because of losses. But The actual output on one machine is 247 nos per day. We can conclude that the average output per day is very low. That leads the production lead time to 4 days for 985 nos. the identified waste at this operation is quality or rejections and waiting time.

Defects at Welding

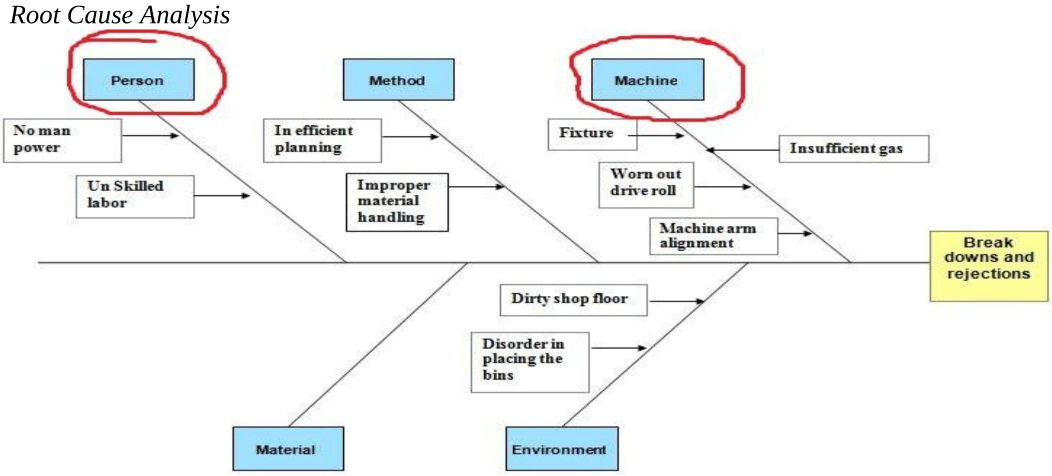
		
DEFECT DUE TO IMPROPER ARM ALIGNMENT	**INCOMPLETE FUSION**	**PERPENDICULARITY**

Work centre description	**Total utilized hours**	**Total non-utilized hours**
Robot welding	71	15

Number of parts produced	**Processing time in min**	**Number of parts rejected**	**Percentage of rejection**
985	2.00	**27**	**2.8%**

The production lead time is 4 days(96 hours) for 985 nos. The total utilized time is 71 hours and total non-utilized time is 15 hours. The remaining 10 hours is planned breaks (tea breaks, lunch break etc.)

- *Root Cause Analysis*



- *Problems Observesd*

Table no 3: problems observed at welding operation

PROBLEM	**CAUSE**	**REMEDY**	**AVERAGE TIME TO REPAIR (Hrs)**
Defects due to perpendicularity	Fixture	Change the fixture	3
Improper wire feed	Worn out drive roll	replace	3
Spatter	Insufficient gas	Ensure proper gas cover	1
	Preventive maintenance		3
Weld path direction	Machine arm alignment	Setter has to check arm alignment	4
Production stopped	No gas		1
			15

- *OEE of Welding Operation*

  Total planed production time = 86 hours.
  Down time = 15 hours.
  Actual cycle time = 2 min.
  Actual production time = Total planed production time - Down time =86 -15 = 71 hour.
  Total quantity produced = 985 nos.
  Good quality = total quantity- rejected quantity = 985 – 27 = 958 nos.

- **Machine Availability =** $\frac{totaltime - downtime}{totaltime} \times 100$

  $= \frac{86-15}{86} \times 100 = 82\%$

- **Performance =** $\frac{Actualcycletime \times number of parts produced}{autualproductiontime(min)} \times 100$

  $= \frac{2 \times 985}{71 \times 60} \times 100 = 27\%$

- **Quality =** $\frac{goodquality}{totalquantity} \times 100$

  $= \frac{985-27}{985} \times 100 = 97\%$

- **OEE =** ***machine availability × performance × quality***
- **OEE** = $0.82 \times 0.27 \times 0.97 = 0.22$

OEE = 22%

- *Turning-Facing–Drilling-Chamfering*

There is WIP in between cutting and(turning-facing–drilling-chamfering). The more waiting Time is found in "turning-facing–drilling-chamfering" leads to longer production lead time.

Takt Time

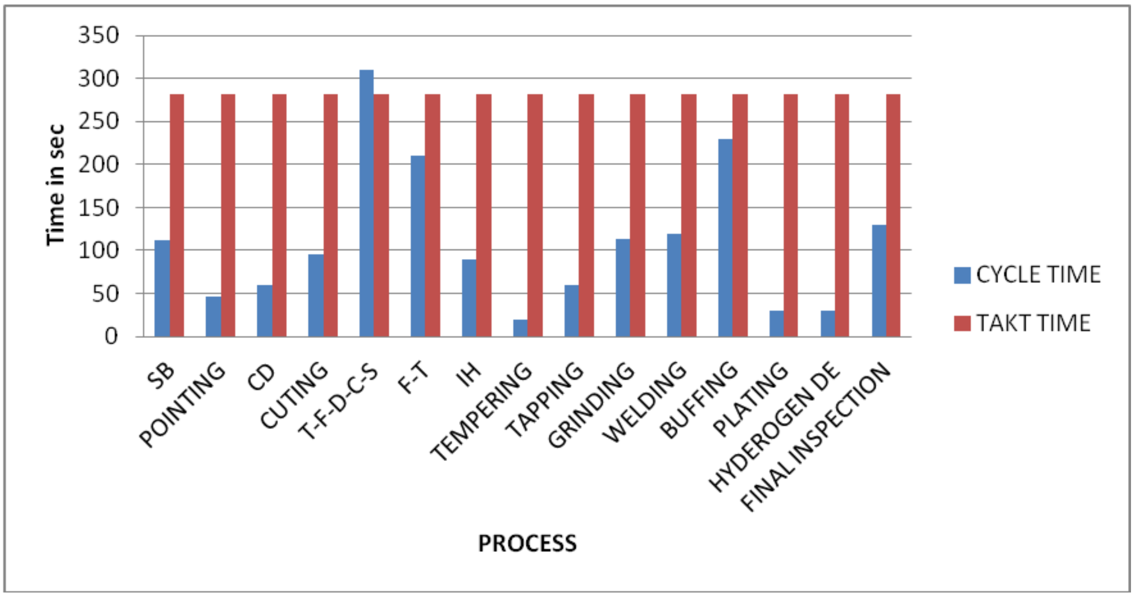
Weekly demand = 1620 nos.
Available working days in week = 6 days

Demand per day = $\frac{1620}{6}$ = 270 nos.

Takt time = $\frac{Netavalibletimeperday}{Customerdemand} = \frac{1290}{270}$ = 4.7 min = 282 sec

From graph the cycle time of T-F-D-C-S is 310 sec and takt time is 282 sec. this operation is the bottle neck for the entire process.

Comparison between Cycle time and Takt time



Future State Map

The future state map is draw to give propose suggestions and recommendations for improvement in the current position of the company.

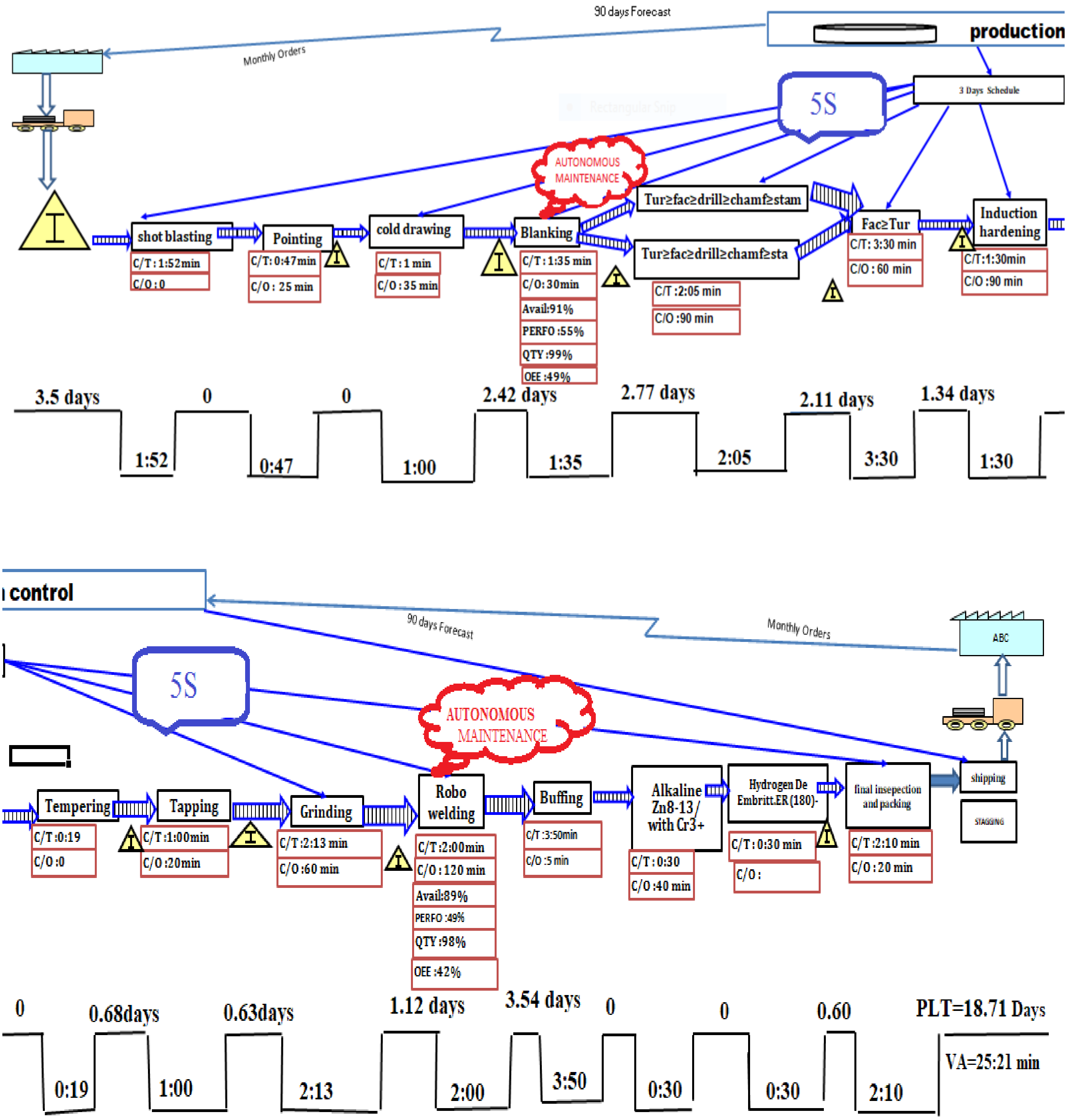


Fig 9: FUTURE STATE VALUE STREAM MAP

- In this process From the current state map Non-value added activities are namely waiting occurs when an operator's work is put on hold because of line imbalances, a lack of parts, or machine downtime; all the downtimes which cause unplanned maintenance at two work stations (cutting and welding) are identified and solved by implementing autonomous maintenance (one of the pillar of total productive maintenance).
- The WIPis removed at Tur≥Fac≥Drill≥Chamf≥Stam by suggestingtokeep one more machine which reduces the cycle time from 5:10 min to 2:05 min and lead time at this operation reduced from 4.22 days to 2.11 days. Also reduction of waiting time caused by WIP from 2.62 days to 0 days.

Suggestions

1. From table 2 and table 3 we can conclude at Cutting and Welding workstations has less productivity per day which leads to longer production lead time due to breakdown. So, here suggested to implement autonomous maintenance (one pillar of Total Productive Maintenance).
2. **Case 1:** There is more WIP in between the process blanking andTur≥Fac≥Drill≥Chamf≥Stamp. Here suggested to keep one more CNC machine at Tur≥Fac≥Drill≥Chamf≥Stam in order to reduce its cycle time to half and also reduce the waiting time of the batch due to WIP.

   OR

   Case 2: We can also suggest to share the resource Tur≥Fac≥Drill≥Chamf≥Stam and Fac≥ Tur operations because Tur≥Fac≥Drill≥Chamf≥Stam has the cycle time 310 sec and takt time is 282 sec. if cycle time is greater than the takt time then producer can't meet the customer demand. So, recommended to perform Tur≥Fac≥Drill (i.e. cycle time would be 270 sec) as one operation and Fac≥Tur≥Chamf≥Stam(i.e. cycle time would be 250 sec) as another operation. Then the cycle would be reduced 310 sec to 270 sec which is lower than takt time (282 sec) then we can meet the customer demand.
3. There was no free space for the moment of material in shop floor and shop floor was dirty because of leakages. Suggested that 5S lean technique can be used to improve the working environment.

V. RESULTS

1. **Implementation of Autonomous maintenance (pillar of TPM)**

a) Cutting

Work centre description	Total utilized hours	Total non-utilized hours
Metal cutting(Horizontal band saw)	69.05	6.20

Table 4: Problems observed after implementation of TPM

PROBLEM	CAUSE	REMEDY	AVERAGE TIME TO REPAIR (Hrs)
Low coolant flow	Coolant nozzle blockage	Remove blockage from coolant nozzle	1.20
Preventive maintenance			5
		Total	6.20

Number of parts produced	Processing time in min	Number of parts rejected	Percentage of rejection
1445	1.58	12	0.8

OEE = Machine Availability × Performance × Quality

- **Machine Availability** = $\frac{totaltime - downtime}{totaltime} \times 100$

  $= \frac{75.25 - 6.20}{75.25} \times 100 = 91\%$

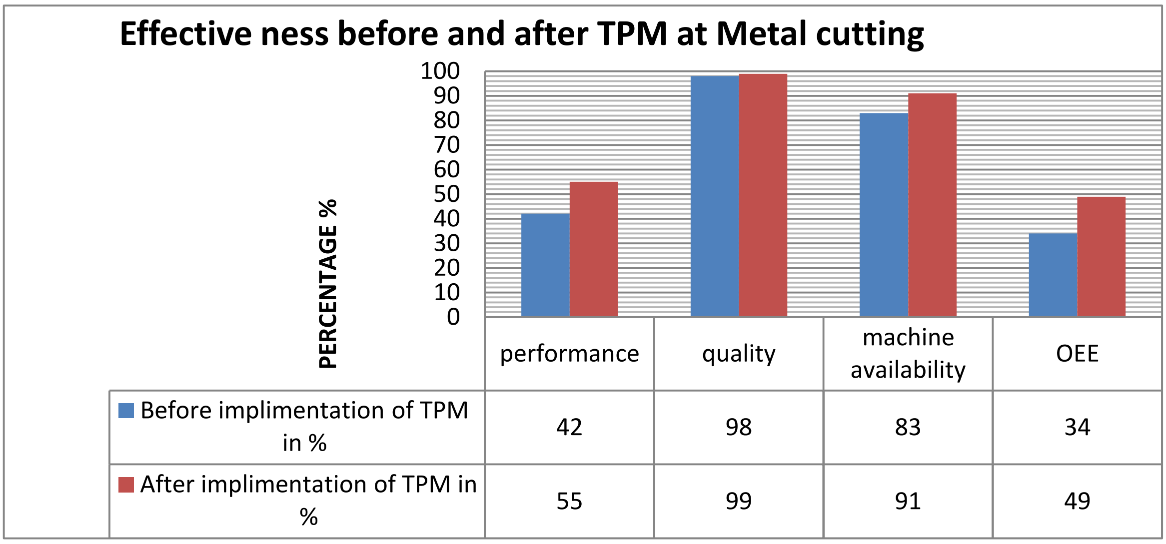
- **Performance** = $\frac{Actualcycletime \times numberofpartsproduced}{operatingcycletime} \times 100$

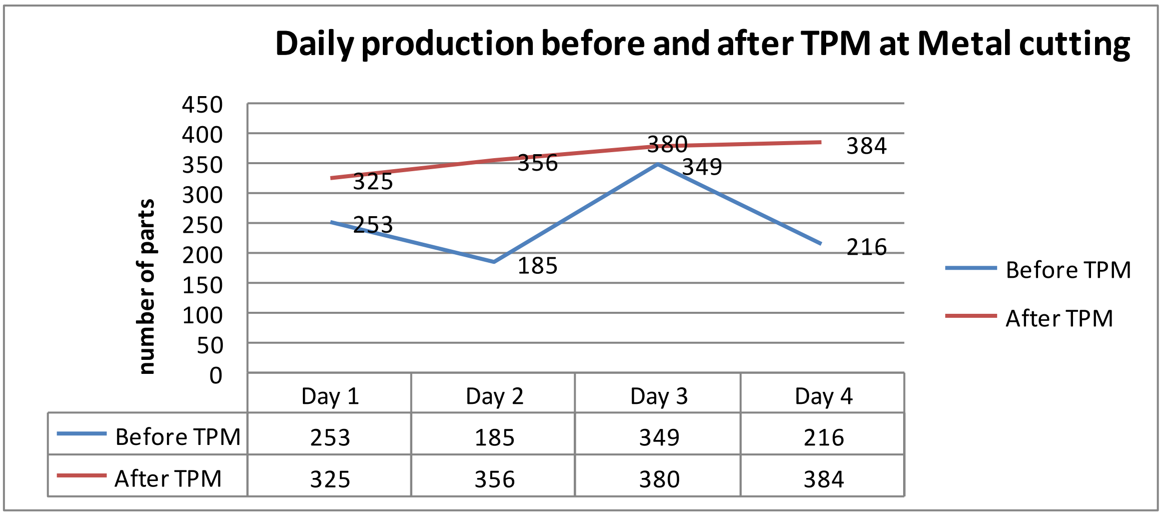
  $= \frac{1.58 \times 1445}{69.05 \times 60} \times 100 = 55\%$

- **Quality** = $\frac{goodquality}{totalquantity} \times 100$

  $= \frac{1445-12}{1445} \times 100$ = 99%
- **OEE** = 0.91 $\times 0.55 \times 0.99$=0.49

OEE = 49%





From the above graph we can clearly observe, before implementation of Autonomous maintenance (one of the pillar of TPM) the production for every day is varying continuously and fluctuations in the daily production due to break downs. After implementation of TPM The break downs are reduced and daily production rate was increased from 286 nos to 361 nos. so, the production lead time at metal cutting was reduced from 3.5 days to 2.77 days because in current state VSM they took 3.5 days to cut the 1003nos after implementation of autonomous maintenance in Future state VSMthey took just 2.77 days to cut 1000 nos.

S.no	Parameters	Before TPM(autonomous maintenance)	After TPM(autonomous maintenance)
1	Non utilized hours	12.50 hours	6.20 hours
2	Machine availability	83%	91%
3	Performance	42%	55%
4	Quality	98%	99%
5	OEE	34%	49%
6	Average parts per day	286 nos	361 nos

7	Production lead time at this process for 1000 nos	3.5 days	2.77 days

b) Welding

Work centre description	Total utilized hours	Total non-utilized hours
Metal cutting(Horizontal band saw)	77	9

Table 5: Problems observed after implementation of TPM

PROBLEM	CAUSE	REMEDY	AVERAGE TIME TOOK TO REPAIR (Hrs)
Improper wire feed	Worn out gun	replace	2
No man power			2
Preventive maintenance			5
		Total	9

Number of parts produced	Processing time in min	Number of parts rejected	Percentage of rejection
1135	2.00	18	1.5%

OEE = Machine Availability × Performance × Quality

- **Machine Availability** = $\frac{totaltime - downtime}{totaltime} \times 100$

  $= \frac{86-9}{86} \times 100 = 89\%$

- **Performance** = $\frac{Actualcycletime \times numberofpartsproduced}{operatingcycletime} \times 100$

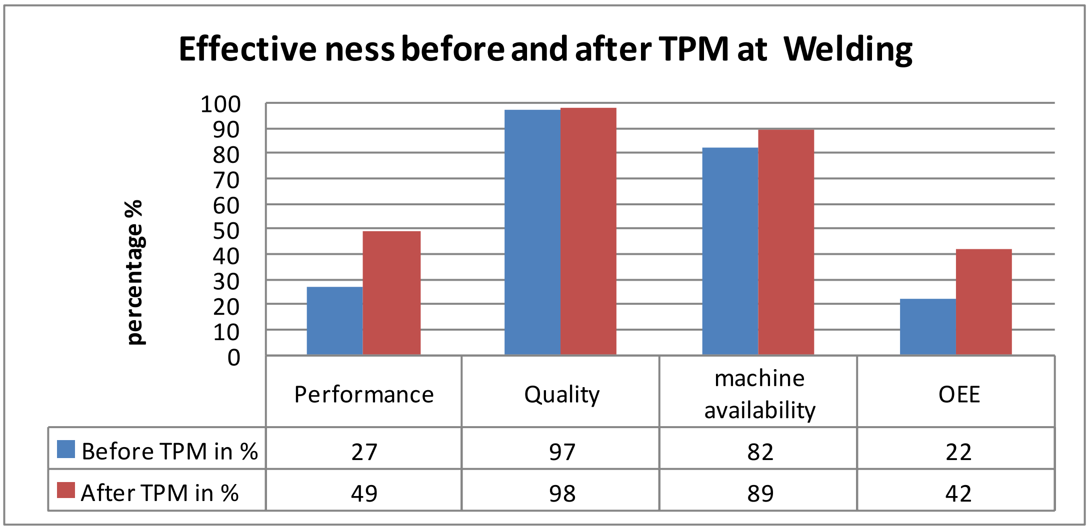
  $= \frac{2 \times 1135}{77 \times 60} \times 100 = 49\%$

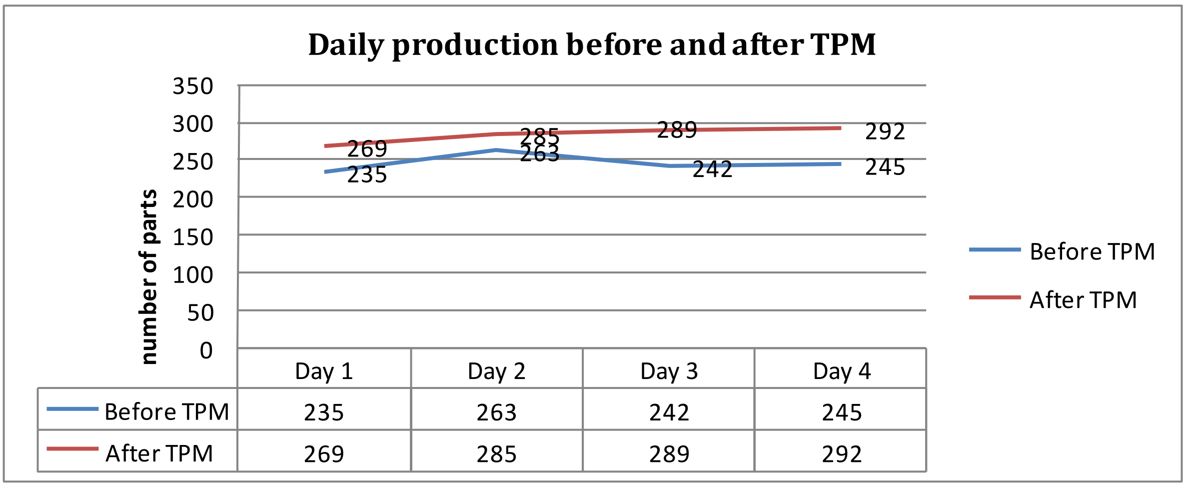
- **Quality** = $\frac{goodquality}{totalquantity} \times 100$

  $= \frac{1135-18}{1135} \times 100 = 98\%$

- **OEE** = $0.89 \times 0.49 \times 0.98 = 0.427$

OEE =42 %



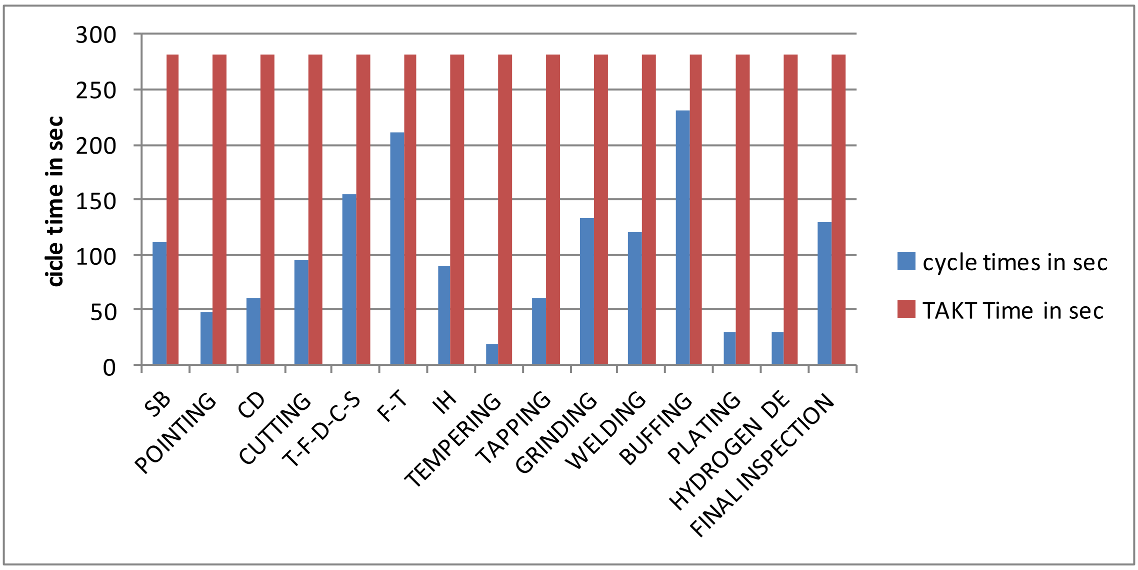


From the above graph we can clearly observe, before implementation of Autonomous maintenance (one of the pillar of TPM) the production for every day is varying continuously and fluctuations in the daily production due to break downs and poor quality. After implementation of TPM The break downs due to poor quality are reduced and daily production rate was increased from 247 nos to 283 nos. so, the production lead time at welding was reduced from 4 days to 3.54 days because in current state VSM they took 4 days to weld the 985nos after implementation of autonomous maintenance in Future state VSM they took just 3.54 days to weld 1000 nos.

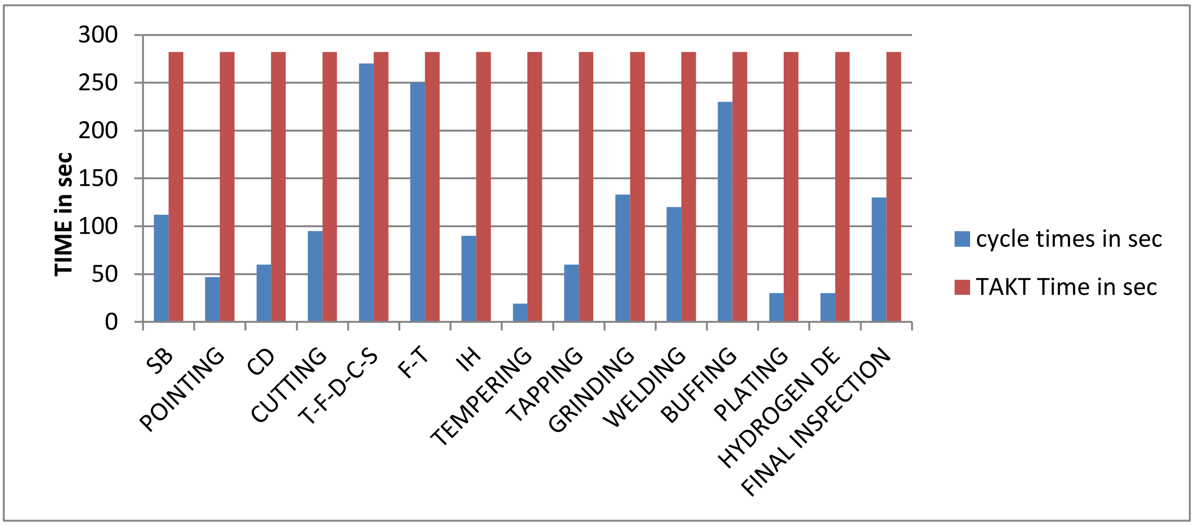
S.no	Parameters	Before TPM(autonomous maintenance)	After TPM(autonomous maintenance)
1	Non utilized hours	15 hours	9 hours
2	Machine availability	82%	89%
3	Performance	27%	49%
4	Quality	97%	98%
5	OEE	22%	42%
6	Average parts per day	247 nos	283 nos
7	Production lead time at this process for 1000 nos	4days	3.54days

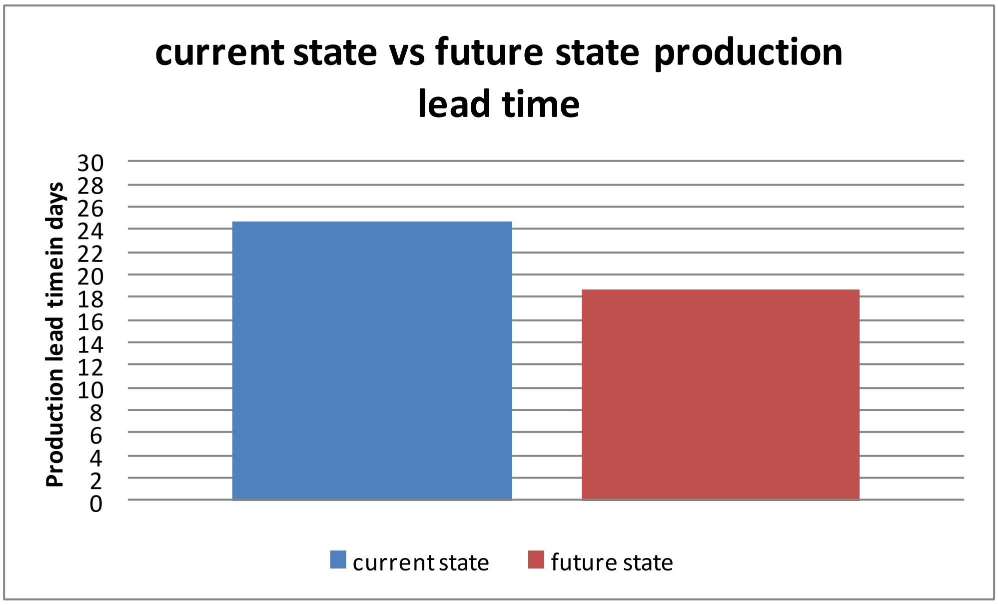
2. Tur≥Fac≥Drill≥Chamf≥Stam (more WIP)

Case 1: If we add one more machine at Tur≥Fac≥Drill≥Chamf≥Stam operation. The cycle would be reduced from 310 sec to 155 sec.



Case 2: If they share the resource Tur≥Fac≥Drill≥Chamf≥Stam and Fac≥Tur operations. So, recommended to perform Tur≥Fac≥Drill (i.e. cycle time would be 270 sec) as one operation and Fac≥Tur≥Chamf≥Stam (i.e. cycle time would be 250 sec) as another operation. Then the cycle would be reduced from 310 sec to 270 sec.





VI. CONCLUSION

After implementing lean concepts (Value stream mapping, Autonomous maintenance, 5S) with 'case 1' at Tur≥Fac≥Drill≥Chamf≥Stamp For product LNK413 manufacturing lead time was reduced from 24.63 days to 18.71 days.

Cutting

1. The total utilized hours was increased from 62.75 hours to 69.05 hours.
2. The total non-utilized hours decreased from 12.5 hours to 6.20 hours.
3. Performance was increased from 42% to 55%.
4. Quality was increased from 98% to 99%.
5. Machine availability increased from 83% to 91%.
6. OEE (overall equipment effectiveness) was from 34% to 49%.
7. Production lead time at cutting operation for 1000 nos was reduced 3.5 days to 2.77 days.
8. Average parts or nos per day increased from 286nos to 361 nos.

Welding

1. The total utilized hours was increased from 71 hours to 77 hours.
2. The total non-utilized hours decreased from 15 hours to 9 hours.

3. Performance was increased from 27% to 49%.
4. Quality was increased from 97% to 98%.
5. Machine availability increased from 82% to 89%.
6. OEE (overall equipment effectiveness) was from 22% to 42%.
7. Production lead time at welding operation for 1000 nos was reduced 4 days to 3.54 days.
8. Average parts or nos per day increased from 247nos to 283 nos.

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