Improving the Productivity of Gearbox Assembly Line by using Lean Methodology

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Abstract- This paper aims to improve the overall productivity of a windmill gear box manufacturing industry by effective implementation of lean principles. According to lean methodology, meeting the customer demand is done by effective utilization of various lean tools like line balancing, kaizen implementations and 5S principles, which makes the assembly process suitable for further continuous improvements. Current State Value Stream Mapping (CSVSM) is plotted to understand the ongoing process in the assembly section of the gearbox manufacturing industry. After that the layout optimization of the assembly process is done to enhance the productivity by optimizing every section of assembly process to work under the takt time obtained from the customer demand. After the layout optimization, Future State VSM (FSVSM) is again plotted to study the improved process in the assembly line.

Keywords: Lean manufacturing, 5s, Value stream mapping, Line balancing, Layout optimization.

1 Introduction

In the current era of globalization, industries are adopting new tools and techniques to produce goods to compete and survive in the market. The most daunting issue faced by manufacturers today is how to deliver their products or materials quickly at low cost and good quality. One promising method for addressing this issue is the application of lean manufacturing principles and techniques. Lean manufacturing, developed first at Toyota, has become a very popular production systems improvement philosophy. The principles of 'lean' focus on eliminating waste and non-value added activities in a process while maximizing the value-added tasks as required by the customer.

Lean manufacturing is one of the initiatives that many major businesses in different nations have been trying to adopt in order to remain competitive in an increasing global market.

Originating from the Toyota Production System, many of the tools and techniques of lean manufacturing (e.g., kaizen, line balancing, 5S, kanban, total productive maintenance, single-minute exchange of dies, production smoothing) have been widely used. Increasing productivity deals with increasing the number of parts produced in a defined time frame (e.g. one day, one shift), this is done by creating substation, eliminating non value added activities and bringing down the cycle time within the takt time. It results in a higher output therefore in higher productivity and thus increases the overall added value within this given period of time. A large integrated gearbox manufacturing company is used to illustrate the approach. Since some of the information is confidential, the company is referred to as ABC drives throughout this paper. In our approach, value stream mapping (VSM) is first used to map the current operating state for ABC. This map is used to identify sources of waste and to identify lean tools for reducing the waste. A future state map is then developed for the system with lean tools like layout optimization and kaizens applied to it.

2 LAYOUT

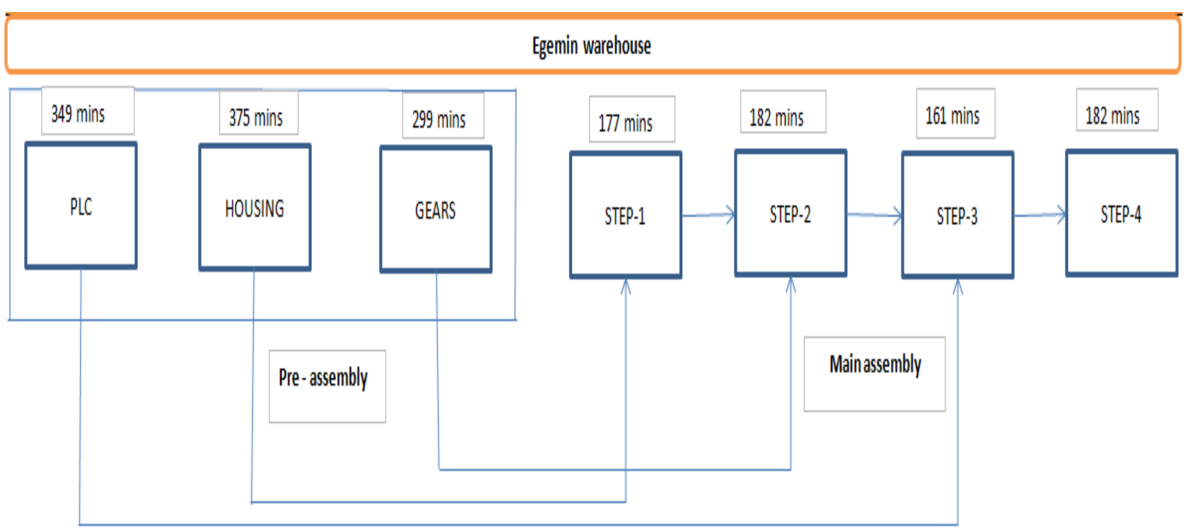

Figure 1 Existing Assembly Layout

The detailed layout of the wind mill gearbox assembly unit of ABC industry is provided in figure 1.The layout consists of three pre-assembly and four main assembly stages. Materials are supplied from manufacturing process through the EGEMIN warehouse, the first step of pre-assembly is PLC which is assembled with a cycle time of 349 minutes and it is sent to third step of main assembly. The second step of pre-assembly is housing which is assembled with a cycle time of 375 minutes and it is sent to the first stage of the main assembly. The third step of the pre-assembly is gears which are assembled with a cycle time of 299 and it is sent to the step two of main assembly. Finally the fourth step of the main assembly is assembled with a cycle time of 182 minutes.

3 PROCESS

The assembly process of the industry is of a 4 staged process which also has 3 pre-assembly stages. These pre-assembly stages act as subassemblies of the main assembly. The four main assembly process of the ABC Company are (i) Assembly step 1 (ii) Assembly step 2 (iii) Assembly step 3 and (iv) Assembly step 4.the output of the four assemblies above is the wind mill gearbox. The four assembly stages are connected with three pre assembly process which act as suppliers for the main assembly of the wind mill gear box. The process layout and the related process improvement operations are documented in this paper for detailed understanding of the ABC windmill gear box production operations.

The time taken for each assembly stages are tabulated below.

Table 1 Process Time

Process steps	Time taken (mins)
Pre-assembly -step-1 (PLC)	349
Pre-assembly -step-2 (housing)	375
Pre-assembly-step-3(gears)	299
Main assembly-step-1	177
Main assembly-step-2	182
Main assembly-step-3	161
Main assembly-step-4	182

The preassembly stages are of 3 different types namely (i) housing assembly, (ii) gears and shaft assembly and (iii) PLC assembly. Outputs of these 3 assembly stages are taken as input to the main assembly process..

In the housing assembly, pipes and bearings are fitted. This assembled part is taken as input to the step 3 of main assembly process. Likewise in the gears and shaft assembly, the sun gears and Low Speed Shaft (LSS) wheels are assembled and the assembled gears are sent to stage 2 of main assembly. The PLC assembly assembles the PLC unit which is sent as input to stage one of the main assembly.

4 Problem Identification

The previous takt time of the industry is 375 minutes which is obtained from its corresponding customer demand of 77 gear box per month. Due to the dynamic market changes the industry faced an increment in its customer demand which is about 99 gear box per month. The new takt time of the industry is calculated as 200 minutes.

This modified takt time was implemented successfully in manufacturing and testing sections, whereas the assembly process could not cope up with this increased demand. The present time taken by all the assembly stage is below 200 minutes but the three pre assembly stages of the industry have the cycle times of 349 minutes, 375 minutes, and 299 minutes respectively in each stage. All three stages are above the takt time of 200.this paper discusses some possible ways in which the cycle times maybe brought within the takt time.

5 Methodology

The first step is to conduct a time study of the assembly line; this is done using a stop watch. Then, current state value stream map is plotted by using the time values obtained from the time study. From the current state map the problem is identified and defined with context to the industry's demand and possible solutions are identified for implementation. These solutions are plotted onto a future sate map. The solutions are implemented in order to improve the productivity. The results of the implementation are observed. The detailed flow diagram of the methodology is shown below in figure 2.

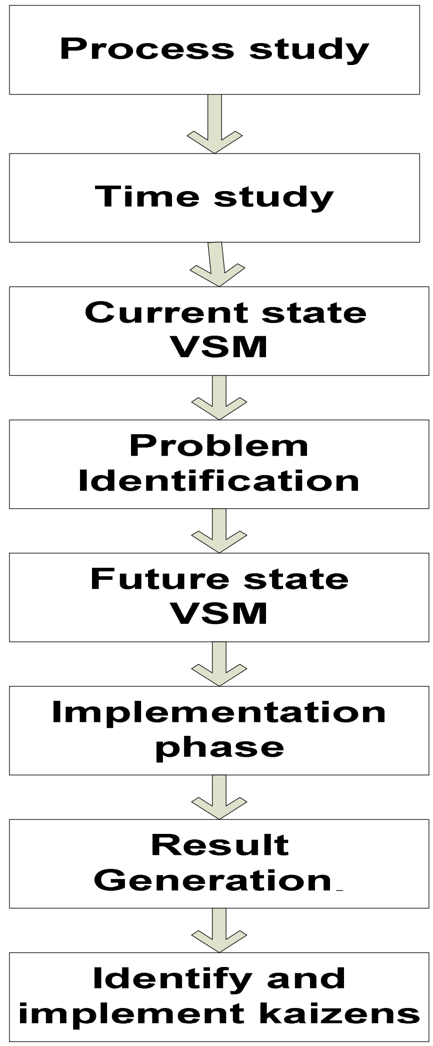

Figure 2 Methodology

6 Process Descriptions

The methodology followed in this study needs a detailed time study which can document each and every value added step in the assembly section with respect to time. So the detailed time study is done which is trailed by plotting of Value stream mapping (VSM) which includes both the current state and future state of value stream mapping.

6.1 Time Study

Time study is the base for work measurement in any manufacturing and assembly process across the globe. The methods of obtaining time values varies from stop watch time study method to automatic time study sheet generation module integrated with high end camera found in modern shop floors. In this project the stopwatch time study method is used for time study. Then each and every process of the assembly process is documented in a separate time study form which is generated from benchmarking the existing time study sheets from the global business consultancy firms. The model time study sheet which is used for documenting the time values is shown below.

Process Study Sheet Time Record	Part No	EH853	Line	GEARS ASSEMBLY	Observer	JEEVA
	Part Name	GEARS	Operator	GNANAVEL	Date	20-Jan-12

Recording Start Time (dd:hh:mm:ss) 0 0 0 0

Process Step	Process	Work Element	End time (dd:hh:mm:ss)				Machine C/T (hh:mm:ss)			Notes	Accept Reject	Real start time (dd:hh:mm:ss)	Real end time (dd:hh:mm:ss)
	Material checking and moving	Note work order number	0	0	0	9					A	00:00:00:00	00:00:00:09
	Material checking and moving	Check mes&log on	0	0	3	20					A	00:00:00:09	00:00:03:20
	Material checking and moving	Search+Check(Components)	0	0	5	9				All component should come through 4x4 pallet	A	00:00:03:20	00:00:05:09
	Material checking and moving	Get gloves	0	0	5	41					A	00:00:05:09	00:00:05:41
	Material checking and moving	Search+Retrive (B T)	0	0	18	16				All component should come through 4x4 pallet	A	00:00:05:41	00:00:18:16
	Material checking and moving	Retrieve Components & Consumables	0	0	28	7				All component should come through 4x4 pallet	A	00:00:18:16	00:00:28:07
	Material checking and moving	Retrieve(B T)	0	0	32	13				All component should come through 4x4 pallet	A	00:00:28:07	00:00:32:13
	Material checking and moving	Get (Ino eye bolt from stand)	0	0	32	21					A	00:00:32:13	00:00:32:21
	Material checking and moving	Install eye bolt & Note Check list	0	0	32	54					A	00:00:32:21	00:00:32:54
	Material checking and moving	Get bearing trolly	0	0	34	37					A	00:00:32:54	00:00:34:37
	Material checking and moving	Get tissue paper	0	0	35	6					A	00:00:34:37	00:00:35:06
	Material checking and moving	Clean(ISS oil screen)	0	0	35	27				No rust prevention oil on the component	A	00:00:35:06	00:00:35:27
	Material checking and moving	Unpack (ISS TRB bearing)	0	0	38	37				[illegible]	A	00:00:35:27	00:00:38:37
	Mount oilscreen and Taper roler bearing	Get & Shaft (oil screen kept in induction heater)	0	0	39	4		14	31		A	00:00:38:37	00:00:39:04
	Mount oilscreen and Taper roler bearing	Check (TRB bearings)	0	0	39	38							

Figure 3 Sample Time Study Sheet.

The output of time study are considered for plotting the current state map

6.2 Value Stream Mapping

Value stream mapping, a lean manufacturing tool which originated from the TPS is known as material and information flow mapping. This mapping tool uses the techniques of lean manufacturing to analyse and evaluate certain work processes in a manufacturing operation. This tool is used primarily to identify, demonstrate and decrease waste, and it also creates flow in the manufacturing process. For each step, parameters include cycle time, TAKT time, work in progress (WIP), set up time, down time, number of workers, and scrap rate. A

VSM identifies where value is added in the manufacturing process. It will also show all other steps where there is non-value added activity. The value stream mapping (VSM) is comprised of two different maps which is current state value stream mapping (CSVSM) and future state value stream mapping (FSVSM). After analysing and evaluating the current process of the product, the problem areas can be identified. Once the current process is changed to minimize problem areas completely, the final state VSM can be plotted. The last step of the value stream mapping process is to implement the proposed improvements into future state mapping, which is nothing but the proposed implementation of the lean tools in the industry to enhance the productivity.

6.2.1 Current State Vsm (CSVSM)

The current state mapping is done according to the time study conducted. The assembly layout from fig 2 consists of four stages of main assembly process with three stages of preassembly process. The pre-assembly consist of about 3 stages with cycle time 375,299 and 349 respectively. The main assembly process consists of about 4 stages with cycle time 177,182,161 and 182 respectively. The cycle time is increased due to the pre-assembly. The CSVSM of ABC industry for windmill gearbox manufacturing is given below in figure 4.

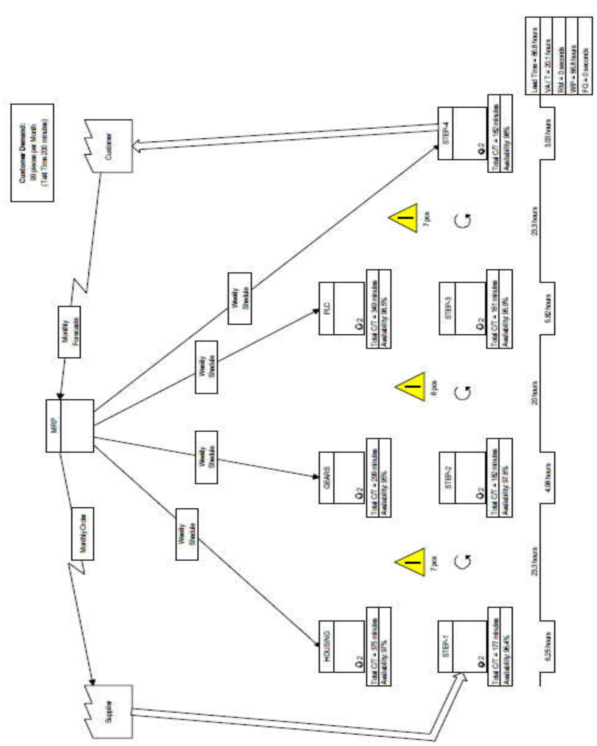

Figure 4 Current State Map Of Abc Drives

7 Implementation

7.1 Layout Optimization

Layout optimization is the main improvement which is done to attain the target takt time of 200 minutes in every step of the assembly process. The modified layout is shown in Annexure1.

The work in progress (WIP) inventory is increased in all pre-assemblies. The heating of slow wheel in step-1 pre-assembly and the heating of ISS wheel in step-2 pre-assembly consumes 300 mins each per part. So another heater is installed to bring down the mean heating to 150 mins which is below the takt time. In Step-3 pre-assembly, WIP is increased to 7 PLC's because of the very long cooling time of 1400 mins. So this inventory helps us to get a cooled PLC for every 200 mins. These inventories are necessary to compensate the heating and cooling time in order to attain the required takt time.

Works balancing of the workers in respective stage are also done to attain the takt time of 200 mins. The work assignment for step-1 pre-assembly, operator-1 who does pipe fitting alone is 198 mins. The operator-2 does slow wheel preparation for 60 mins and the pipe fittings step-2 for other 90 mins after that slow wheel pressing for other 50 mins. In total he has an total cycle time of 200 mins . In step-2 pre-assembly the operator-1 completes the gears step-1 at 201 mins and the second operator takes 90 mins to complete gears step-2 and he supports the step-1 pre-assembly operator-2 to insert the slow wheel. In step-3 pre-assembly operator-1 takes 197 mins to complete step-2 and the operator-2 takes 200 mins to complete other assembly

In the housing assembly the gears are inserted inside the housing using the separate wooden weights a height adjustment tools and this setup formation alone utilizes about 30 minutes of the total working time of the operator in the housing stage of assembly process. For reducing this process time, a separate fixture named as Hydraulic car rail has been designed as shown in the figure 6 below, and this is reduced from 30 mins to 17 mins of the setup time.

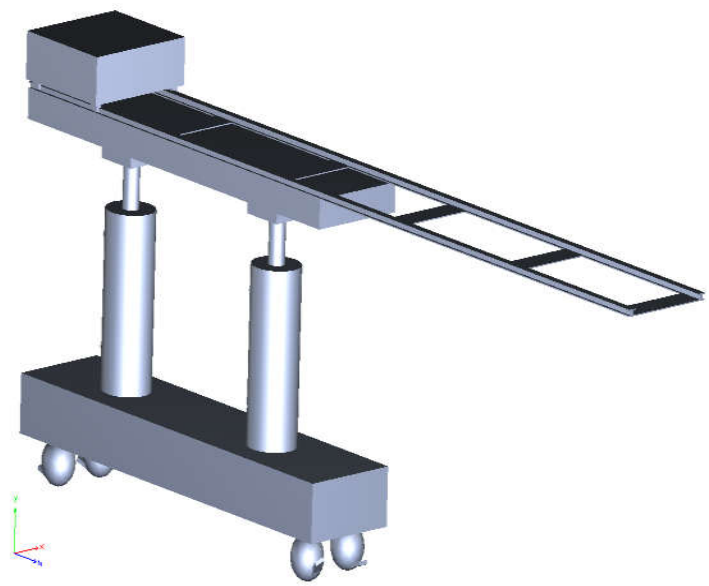

Figure 5 Hydrallic Car Rail.

6.2 Line Balancing

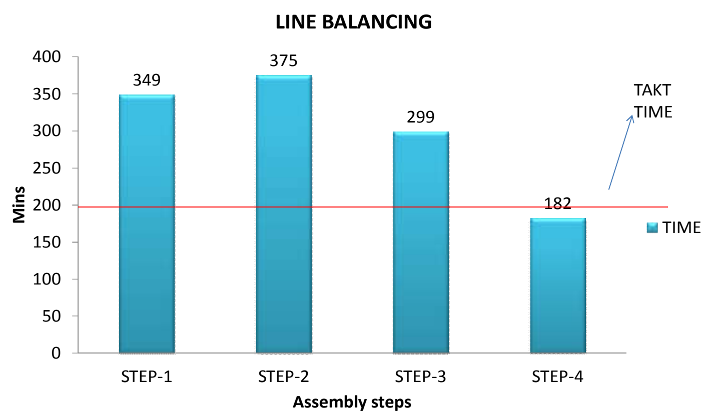

Figure 6 Workstations Before Line Balancing

The first three steps have a higher cycle time so it crosses the current takt time value of 200 mins. The line is now unbalanced.

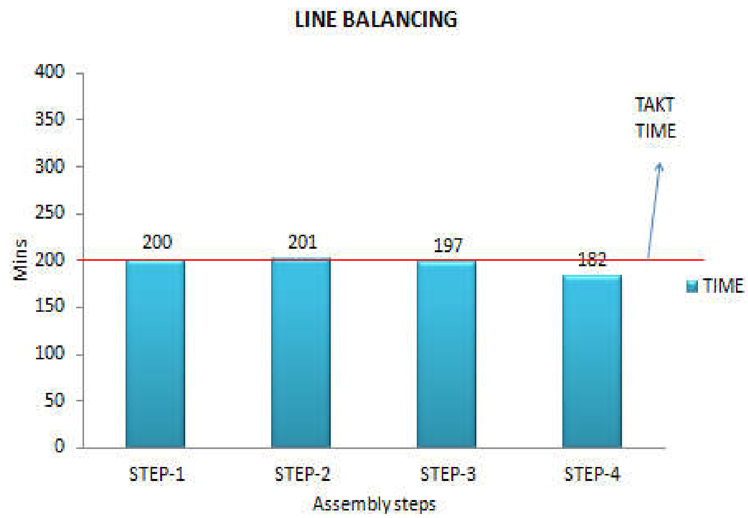

Figure 7 Workstations after Line Balancing

After implementing the solutions discussed in section 6.1, all the steps in the assembly have a cycle time less than that of the takt time due to the layout optimization. Now the line is balanced.

7 Results and Discussion

7.1 Future State Mapping (FSVSM)

The future state map is a process of plotting a map in which the process of plotting includes the new changes which is proposed and should be done to solve a problem identified in current state VSM (CSVSM). Likewise this future state VSM (FSVSM) map is also included with the various process improvements suggested like line balancing of pre assembly and other kaizen events which are done in order to make the assembly process to meet increased customer demand. The FSVSM process is a document which forecast the effect of proposed improvements done in the shop floor and relating it to the customer demand. It also act as an justification document for sanctioning the financial help from the accounting department.

The future state value stream mapping (FSVSM) complete with the changes is shown below in figure 8.

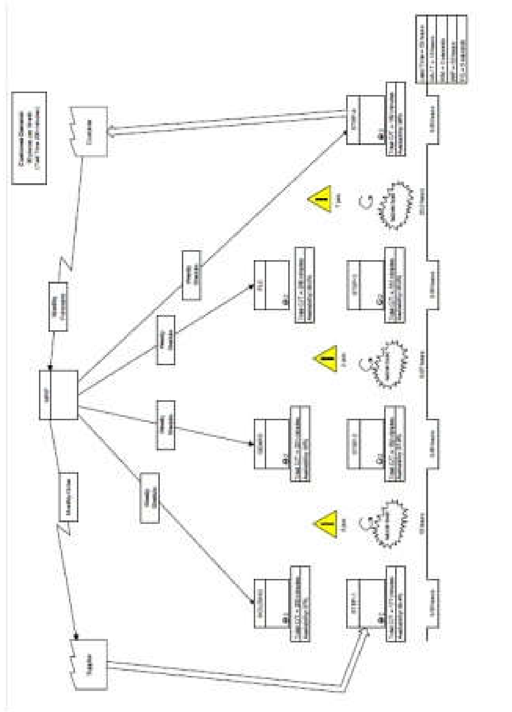

Figure 8 Future State Vsm

7.2 Simulation Process

The simulation of the assembly process is done using the ARENA10.0 software which gives out the output as report file which has the amount of machine utilization, the productivity of assembly process for fixed time (day, month, etc) and waiting period of the parts in the assembly process. The main aim of the simulation is to justify how far the proposed changes in the future state can affect the productivity and to estimate the level resource utilization in particular stages of the overall assembly process.

The simulated model using arena is given below in figure 6,7 which is modelled by taking the time values obtained from the time study.

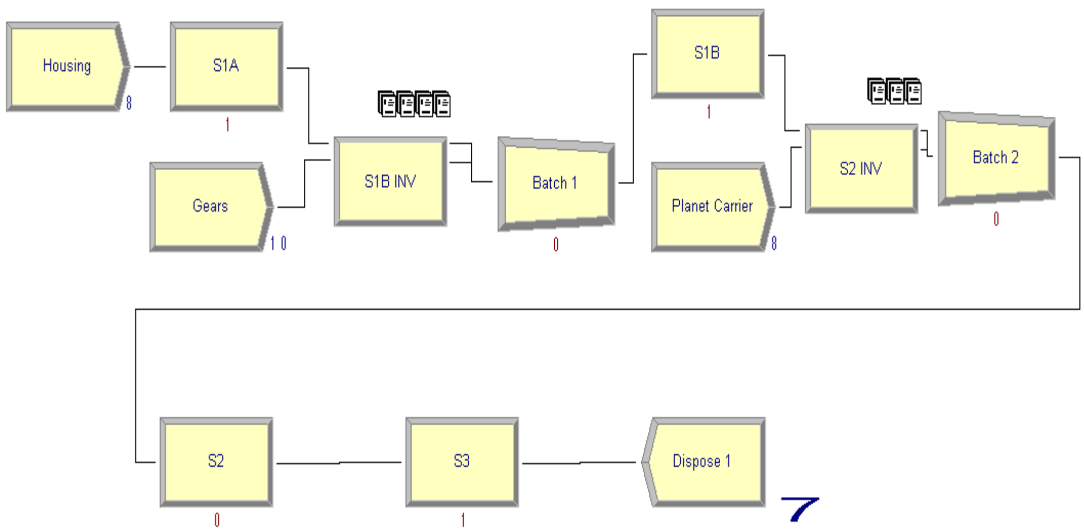

Figure 9 Current State Simulation Model

The simulation model is then run in the computer to simulate the assembly process with working conditions found in the assembly section of shop floor as its parameter after which the output is documented for analysis.

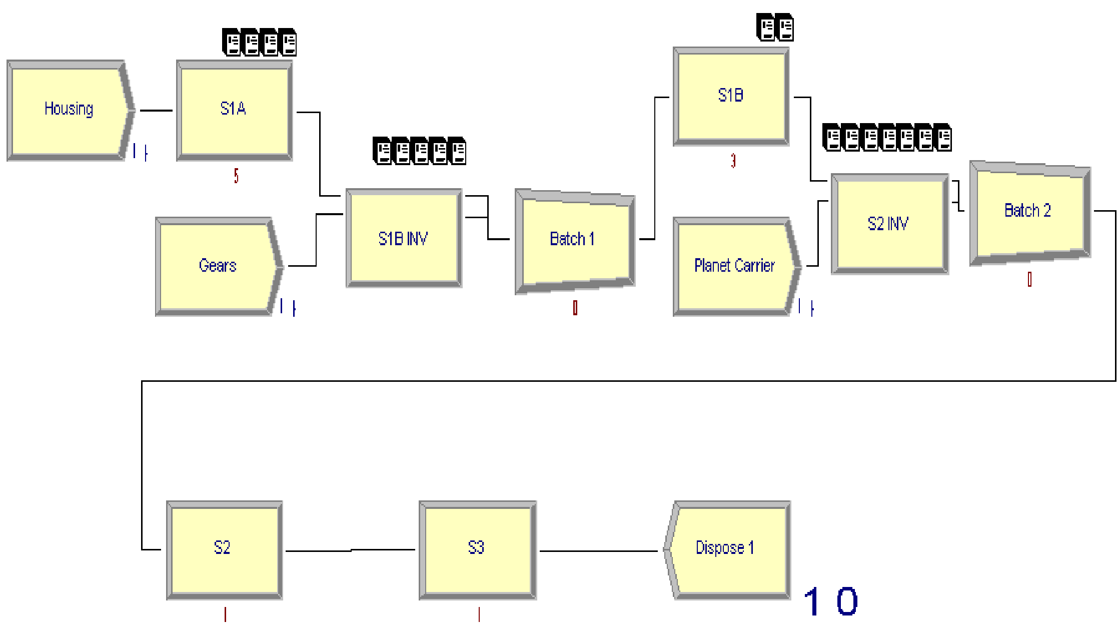

Figure 10 Future State Simulation Model

The current state is simulated in the simulation model and run to provide output result. From the output, is found that 77 gearboxes per month are produced. It is again simulated with necessary changes e proposed in the future state of the VSM included in the simulation model and again run to simulate the result .

The output results are found to be 110 gear box per month which is more than the customer demand of 99 gearboxes. Thus this simulation process confirms the fulfilment of customer order with the proposed changes which is proposed in future state value stream mapping (FSVSM).

The total impact of the improvements in the productivity achieved are shown in the below table 2

Table 2 Impact Of Improvement Table

parameter	Before implementation (minutes)	After implementation (minutes)
Takt time	375	200
Productivity per month	77 Gear box	110 Gear box

The table above can be depicted as a graph (figure 11) to visualize the amount of productivity improvements done to meet the customer demand.

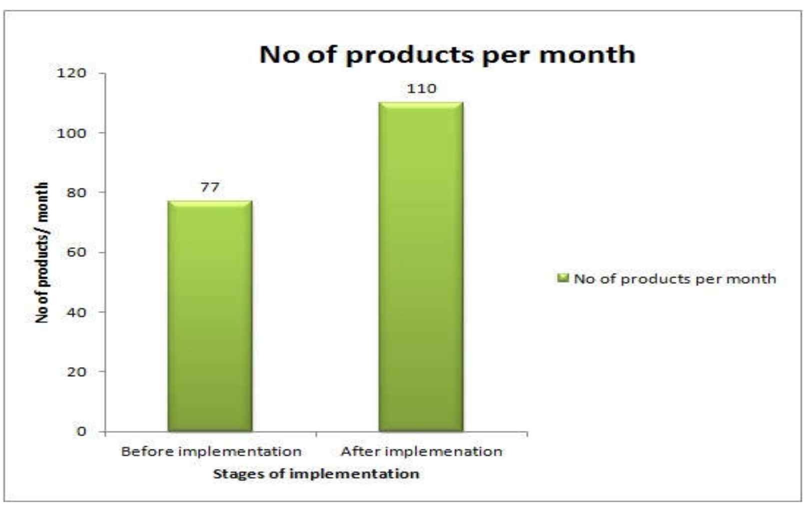

Figure 11 Productivity Improvement

8 CONCLUSIONS

The productivity of the windmill gear box manufacturing plant has been improved from 77 this gearboxes per month to 110 gear boxes per month, is achieved by reducing the takt time of the industry after addressing several constraint problems with its assembly process in the shop floor. The problems are solved with the help of Lean methodologies and other lean tools as explained. This has also helped in layout optimization of entire pre-assembly process. In future if the company wants to improve its productivity further from the present takt time then company first need to line balance the preassembly process which is considered as the bottle neck operation in ABC Industry.

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