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SYSTEMATIC EFFICIENCY IMPROVEMENT BY OPTIMIZING THE ASSEMBLY LINE USING WITNESS SIMULATION SOFTWARE

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***Abstract*−Today's customers demand high quality, customized goods and services, quickest delivery. This has made the design and management of systems more challenging. Simulation models are used to find various aspects of manufacturing systems. Manufacturing industries need plant layout improvements to meet their customer demands. This paper provides the use of Witness Simulation to design the production of a manufacturing company that reconditions Cam follower for export demand. The objective of the study is to increase the productivity and efficiency of the line. Detail knowledge of the assembly line is must and analysing the present needs is important. Cycle time data is collected by stopwatch for every station of respective assembly line. The bottlenecks of the production line, required man, machine and other major causes of the problems were identified. Modifications in the model structure to improve the assembly line is made to improve the total output. The analysis presented through the simulation here reduce the manpower of assembly line with the same production output of 2500 yield per month.Earlier 26 manpower were present per day, through simulation output, 6 manpower are reduced. The relevance of the study is by planning to optimize resources, cost of company is reduced with better profits. Also VSM and OEE study, helped improve the effectivity and productivity of assembly line. By eliminating the root causes for failure of product, the product has become more reliable. Overall the quality of product is improved to 96.00 percent.**

Keywords*− *Witness Simulation, Assembly line, Value stream mapping, Overall Equipment Effectiveness, Bottleneck, Productivity improvement.

I. INTRODUCTION

Manufacturing is a competitive global market and the plant layout problems are found in every manufacturing industries. To maintain the plant layout is a major challenge and they are known for impacting the performance of the entire production system. Cam Follower is one of the complex part of engine and the acceptability performance of a cam follower system lies in its testing. There is a need of high accuracy of precision in processing. In this paper, the problem definition are the issues reported in Manufacturing Company. One of the Manufacturing product is Cam follower. They work for the International markets and provide the conditioned products with 100% quality assurance to Australia, Denver, Chile. Processing of the Cam follower has a process sheet to be followed. According to the investigation, some problems were detected that had severe impact on failureof engine field. This impacted delay inbusiness. The hardware equipment's drop behind comparatively, in addition the management efficiency is very low in this production line. From the production data, they produce 50 Cam followers per shift. And their yield is approximately 2,500 per month. The whole set up need to be redesigned again as there is addition of new machines in to the setup. Therefore, the overall goal is to achieve quality product and to meet the customer demand and satisfaction. This business is a new concept introduced in India. Manufacturing means conditioning of the core parts. The Company offers a wide range of manufacturing and build up products that are like the new parts. A fixed standardis maintained in the manufacturing process that make components and engines that do provide same quality with 100% inspection certification standards. The Customers for whom time is money and for whom the product demand is very urgent, in such case the Manufacturing Company provides the products in stock, rather than waiting for the new parts, the exchange business of core replacement is done.

II. ROLE OF SIMULATION IN MANUFACTURING

Recently, there is growing demand of simulation in manufacturing industries. Evidence of the use of simulation can be found out using the literature. Simulation has much to offer all large organizations, whether they are in manufacturing or in the service industries. The role of simulation is to evaluate practical alternatives available either in support of major strategic initiatives which might involve a large financial outlay, or in support of the continuous search for better performance at operational and tactical levels. Sayed Ali [1] evaluation included changes to the machine setups, increases or decreases in customer demand, improvements in cycle time efficiency, reduced lead times and improved customer responsetimes, getting knowledge about the breakdowns in assembly line, the man power requirement analysis. G. Cheng [2] evaluated bottleneck operations in the assembly line. It is capable of handling the complexity of large systems, even a whole factory. The simulation approach supports critical analysis by allowing rapid changes to the model logic and data. From above discussion it can be said that Witness Software is user friendly. Lanner Group Manufacturing Book [3] suggested that the Simulation Software enables business process improvement for world leading organizations. With simulation business managers can model, analyse and optimize processes to make superior decisions in a risk free environment. Witness simulation is the key to improving productivity, efficiency and reducing cost. Ramasesh [4] provided research on dynamic job shop scheduling and sequencing problem to improve the performance of flexible manufacturing systems. Yabin Li [5]the use of Witness simulation software in optimization of the thermal power plant. Transport of the coal was improved by improving the railway tracks. The model explains the construction of process and validates the feasibility of model.

III. MODEL BUILDING

This section explains the simulation study of the assembly line that is being practised in the Manufacturing Company. As discussed earlier the main purpose is to improve the quality of the product.

A. Assembly Line

Assembly line has been used in a mass production system. The conceptual model has been shown in Fig 1. The assembly line includes a number of workstations arranged in a sequence. The workstations are semi-automated, where an operation is done by a machine and operator.

The parts are carried by trolleys from one station to next. The parts of Cam Follower are very fragile. Therefore to reduce any dents and to avoid crack marks, the operation department has done the material handling improvements as well. Separate bins are designed to keep subparts of the whole assembly.

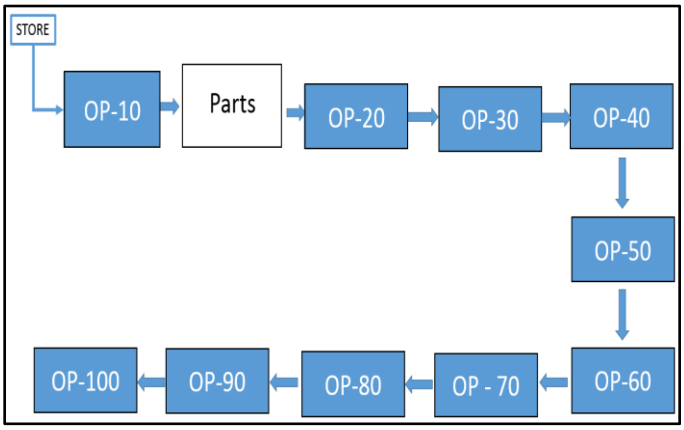

Fig 1. Conceptual Model of Previous Assembly Line

There are improvements in the future processing assembly line. Fig 2 shows the future conceptual model for the cam follower line. From the comparison of both the conceptual layouts, it can be observed that there is increase in workstations and machineries in the future assembly line layout. Also the man power requirements has increased. Therefore, we need to determine the optimum man power required in the future assembly line without affecting the production rate of Cam follower. Maintaining the same production rate as per previous model can be simulated using Witness Software.

The study showed that the previous model had problems. The bottleneck operations were studied. In the Fig1. OP-60 both used to get pressed on single station. There was only one press machine on which three operations were performed respectively. It was found that the set up time was more as every time the operator had to fit different fixtures for the particular operation to get performed. Also it was found that there was no failsafe method used. Therefore, it resulted into misalignment and wrong orientation of the cam follower assembly. There are long downtimes over assembly line. Also there were issues in quality inspection because of dent marks and cracks on the assembly parts. Redesign of the process flow was made.

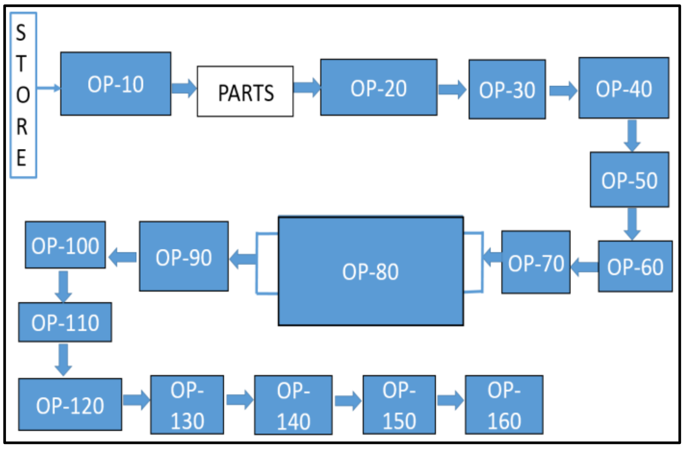

Fig 2. Conceptual Model of Improved Assembly Line

Fig 2 shows the Cam Follower Process flow that is being practised. Here, the number of workstations are increased. It is made sure that the components passed from one station to other is dent free and is inspected thoroughly. There are 4 press machines installed on the assembly line for different part numbers. The OP-80 and OP-90are separately mounted. There is no need to set the fixtures. The fixtures also has the failsafe method to avoid wrong orientation. Hence, the production rate is not hampered and the company can meet it's per day target. There were further improvements made from the quality prospective of the product. OP-40 and OP-100 for every part was carried out. OP-120 and OP-140 station were introduced to improve the quality of subparts.

B. Data Collection and Analysis

The duration for developing the simulation model is all dependent on the amount of quantifiable and quality data that is being collected from the assembly line. The keen observation of every activity on the shop floor is equally important as it gives precise idea while designing the simulation model. In this Projectstopwatch tool has been used for gathering data in theproduction line. The cycle time of each station has been captured as a sample for about 10 times.

IV. EFFICIENCY IMPROVEMENT OF PROCESSING LINE OF CAMFOLLOWER

A. Value Stream Mapping of Cam Follower Line

This process is a part of the continuous improvement toolkit, that helps determine the best ways to improve product flow through a facility. VSM is useful to find and eliminate waste. Assembly layout focuses on flow, and the logistics of getting the product to market most efficiently.When it is needed to expand, Value Stream Mapping can uncover valuable opportunities to streamline using Lean thinking. Hence it will be helpful in reducing cycle time and total work content. This sheet is also helpful for operator balance chart to make effective use of operators. Fig 3.shows the VSM of an assembly line.

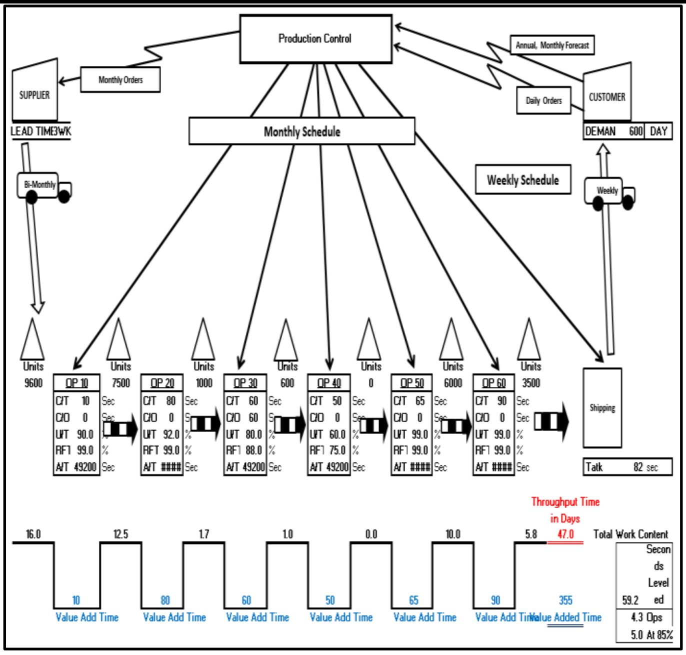

Fig 3. Value Stream Mapping of Assembly Line

i. Time Calculations

Total available time = 780 mins in 2 shifts
Available time/ shift = 420 mins
Consider first work station, for OP-10 Station: -
Cycle time (min) /set = 3.6 min
Uptime = 95 %
Yield = 85%
Batch/ Single = Single
Manpower = 1
Average time (A/T) = 780 * 0.95= 741 mins (1)

$$\text{Possible o/p (unconstraint)} = \frac{Available\ time}{Cycle\ time}$$

$$= \frac{741}{3.6} = 205.83 \qquad (2)$$

$$\text{Output after yield consideration} = \frac{Possible\ output}{Yield}$$

$$= \frac{205.83}{0.85} = 173.95$$

(3)

$$\text{ECT (mins)} = \frac{Total\ time\ per\ shift}{Yield}$$

$$= \frac{840}{0.85} = 4.80 \text{ mins} (4)$$

In the similar way, other stations effective cycle time is calculated.

Two conditions were considered – with constraints and without constraints the effective cycle time is calculated and the demand is the output of the 2 shifts.

For the Packaging Station, the production target is of 100 cam follower from 2 shifts, therefore the takt time is calculated.Takt time simply reflects the rate of production needed to match the demand.

$$\text{Takt time}= \frac{Available\ time}{Desired\ output\ demand}$$

$$= \frac{780}{100} = 7.80 \text{ mins} \quad (5)$$

For each stations there is different demand and hence the takt time is different.Analysis sheet and graphs were discussed with top managers to fix the production target. As a result, the VSM of Cam Follower increased the production target from 100 cam followers to 120 cam followers in a day respectively.

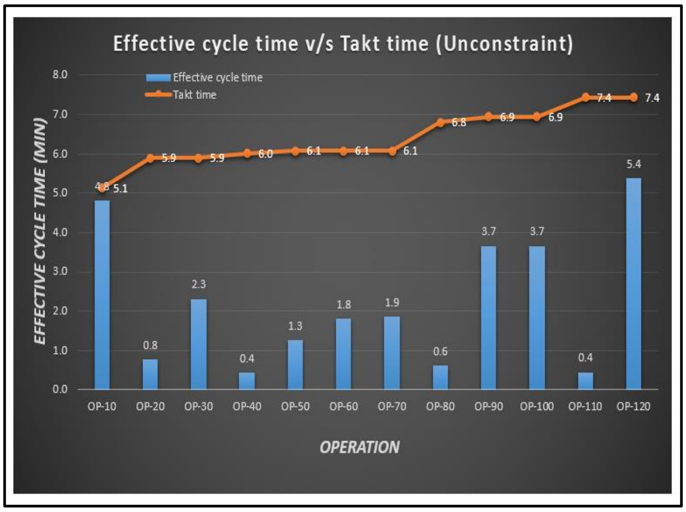

Fig 4. Cycle Balance Chart

The analysis is done based on the balance chart. It gives the idea regarding takt time v/s effective cycle time of individual station respectively. The above takt time line is the generic line for the individual workstations calculated on the basis of overall available time and demand on each workstation. The unconstraint graphs means each workstation has its own inventory and hence production of former is not affected by later. The balance chart in Fig 4. shows that the effective cycle time at every station is less than the takt time line. From the analysis, it is being concluded that production line is in safe zone.

According to the time calculation, the month-yield will increase to 120 by this the first optimization manufacturing line and day-yield will be 60.

ii. OEE Calculations for an Assembly Line

Overall Equipment Effectiveness (OEE) measurement quantifies how well amanufacturing unit performs relative to its designed capacity,during the periods when it is scheduled to run. It is a way of measuring theeffectiveness of a machine which evaluates and indicates howeffectively a manufacturing operation is utilized. Fig 5. is the OEE Model. It shows that OEE has 3 components – Availability, Performance and Quality. This components has six big losses that are tried to be reduced to the run machines efficiently.

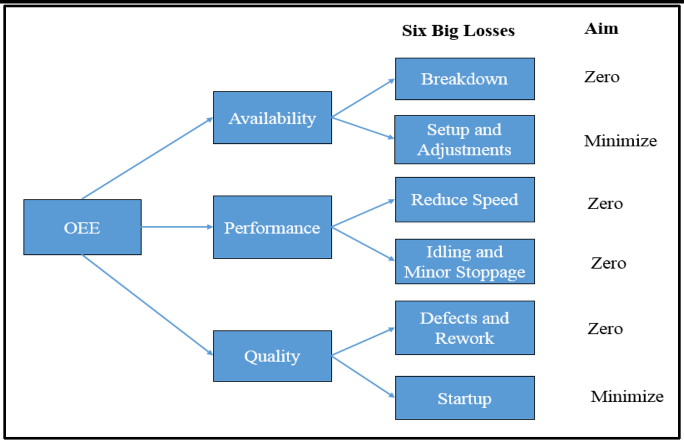

Fig 5. Overall Equipment Effectiveness Model

The high-level formula for the lean manufacturing OEE is:

OEE = Availability X Productivity X Quality

Calculation of Line Balancing:

Available time= 480 min per shift
Lunch Break= 90 min
Available Time= 390 min
Marketing Requirements= 2500 Cam followers/ month
Working Days = 25 Days
No. of shift in a month= 25 × 2
Per shift requirement of Cam Follower = $\frac{2500}{50}$ = 50 Nos.

$$\text{Ideal Run Rate} = \frac{50\ Cam\ Follower}{6.5\ hours\ per\ shift}$$

=8 Cam follower/Hour (6)
Total parts = 2500 / month
Planned production time (PPT) = Shift length – Breaks
= 480 – 90 = 390 min per shift
Operating time = PPT – Downtime = 390 – 10 = 380 min
Assume yield = 95%. Therefore 2 rejected per shift.
Good pieces = Good parts – Rejected parts
= 50 – 2 = 48 Cam followers.

$$\text{Availability} = \frac{Operating\ time}{PPT}$$

$$= \frac{380}{390} = 97.43\ \% \quad (7)$$

$$\text{Performance} = \frac{Total\ parts/Operating\ time}{Ideal\ run\ rate}$$

$$= \frac{2500/390}{8} = 80.1\% \quad (8)$$

$$\text{Quality} = \frac{Good\ parts}{Total\ parts}$$

$$= \frac{2400}{2500} = 96\ \% \quad (9)$$

$$\text{OEE} = 0.97 \times 0.80 \times 0.96 = 0.74 \quad (10)$$

iii. Comparison between World Class OEE and Cam follower assembly process

TableI: Comparison of World Class OEE Factor and Cam follower Assembly Process

OEE Factors	Comparison Chart	
	World Class	Cam Follower Assembly Process
Availability	90.00%	97.43%
Performance	95.0%	80.1%
Quality	99.9%	96%
OEE	85.0%	0.74%

TableI shows that average OEE rate in manufacturing plant is 74 percent.As shown above, a world-class OEE isconsidered to be 85 percent or better. The losses mainly are downtime losses, speed losses and quality losses which affect Overall Equipment effectiveness of the process. To minimize these losses and to achieve world class OEE there should be reduction in events. The main events which are responsible for losses in assembly process are

- Tooling Failures
- Unplanned Maintenance
- Setup/Changeover
- Material Shortages
- Operator Shortages
- Incorrect Assembly

It is important to decrease these non-productive events which affect efficiency of the process. They can be reduce by implementing new techniques and tools, proper inventory storage, in line assembly, skilled labours, special purpose machinery etc.

B. *Witness Modelling and Ameliorating*

The design route are as follows for Witness Simulation table:

Analysis of practical production system → Setting up Witness Model → Discussing the model structure → Finding problems → Putting every parameter in VSM to Witness Model → Establishing witness model after optimizing (according to the VSM and then optimizing again) → Simulation running.

Fig 6.shows the simulation of cam follower production in Witness Model. The total simulation time considered is 56800 seconds. The total output is 110 cam followers per day (100 cam followers approximately). It is targeted that the new improvements in the assembly line does not affect the production rate. Table II shows the statistic report of 13 manpower. There idle and busy percent is known and based on it the operators can be optimized in Witness.

Structuring previous assembly line through witness simulation:

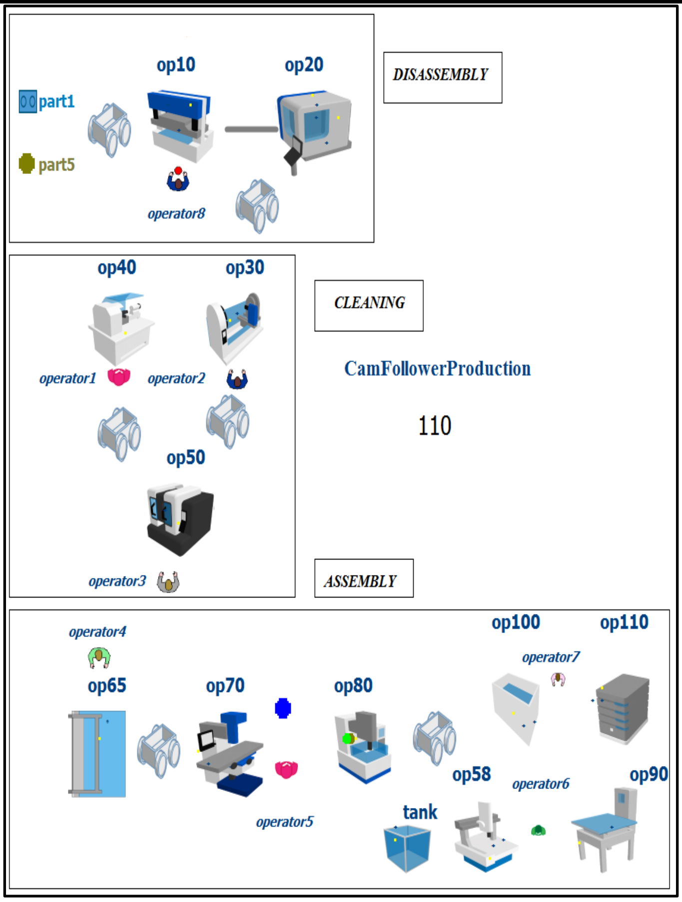

Fig 6. Previous Model of Cam Follower Assembly Line

Table II: Statistics Report of Manpower

Opx. No.	ManPower	% Busy	% Idle	Avg. Job Time	No. of Jobs started	No. of Job Ended
OP 10	op1	100	0	60	947	946
OP 30, OP 35	op2	49.1	50.9	22.61	1233	1232
OP 20, OP 30	op3	98.62	1.38	120.15	467	466
OP 40, OP 50	op4	45.88	54.12	85.72	304	304
OP 55	op5	13.38	86.62	38	200	200
OP 60	op6	86.98	13.02	78.54	630	629
OP 60	op7	71.05	28.95	61.23	660	659
OP 60, OP 70	op8	2.76	97.24	1.44	1092	1092
OP 80, OP 90, OP 100	op9	26.71	73.29	10.38	1462	1462
OP 110, OP 120	op10	50.46	49.54	24.01	1194	1194
OP 130, OP 130	op11	58.52	41.48	196.67	170	169
OP 160, OP 150	op12	39.32	60.68	67.68	330	330
OP 140	op13	46.85	53.15	241.94	110	110

The model gave the machine and manpower statistics report that suggested the overall results of individual stations and operator work respectively. It gives the busy, idle, blocked percentage data.

Some problems were found in the assembly line.

1) As shown in Fig.2 some stations were added into the Cleaning area.

2) It is being noticed that the manufactured cam follower is having rust and dent marks on its assembled parts. Therefore, there is a need to work on quality of product.

3) The quality team improved it by ordering new inspection gauges, by adding the workstations such as dye penetrant testing, de-watering method, rust prevention method and oil flow test and lastly by giving proper training to the operator.

4) New press machines were introduced so that there is a reduction in setup time of fixtures.

5) There is a failsafe method used on every fixture to avoid misalignment of parts.

6) With the help of VSM of cam follower line demand of new line per shift is determined. Hence, the new improved assembly line is setup.

C. Suggested Model through Witness Simulation

Witness model of improved layout targeted two things: -

- Manpower requirement per shift and
- Production output per day.

The total simulation time considered is 56,800 seconds (i.e. 976 minutes in a day).Total time considered by excluding the break and lunch time is 390 mins per shift and 3 hours in night shift. In this company, there is more human involvement. Although there are machines but the man capacity is equally important and is needed to be always maintained to meet daily production capacity.

Trials were held many times. Firstly, the line is set up. Next the manpower needed to determine. The line simulated as per the planning of team. The Production team demanded 26 people per day (i.e. 13 people per shift). The Operation team felt that unnecessarily there is extra use of labour. So they asked to release the labour. Here, the virtual simulation in Witness role came in. The statistic reports from the simulation showed the actual busy and ideal time of individual operator in process. Trials were being held to combine the work of operators. These reports helped optimize the manpower.Results showed that 3 man power can be released to other assembly lines without affecting the production rate.

There is major cost saving to the organization. This can be shown through the following calculations.

Total Manpower = 26 per day
Assume: Cost of one Cam follower = Rs.16,000
Cam follower production per day = 100
Production of cam follower per week = 600
Cost per week = 600 × 16,000 = Rs.9,600,000 = $1,51,286

$$\text{Labour Productivity} = \frac{Input}{Output} \quad (11)$$

Case I: The company generated $1,51,286 worth of Cam follower in one week with 26 operators.
Labour productivity can be calculated by giving input as hours of work per week:

$$\text{Labour Productivity} = \frac{Total\ cost\ per\ month}{Total\ No.of\ working\ Hours}$$

= $1575per Hour of work (12)

To calculate the labour productivity in terms of individual operator's contribution:

$$\text{Labour Productivity} = \frac{Total\ cost\ per\ month}{Total\ No.of\ Employess}$$

$$= \frac{\$\ 1{,}51{,}286}{26}$$

= $ 5,818 perEmployee per week(13)

Case II: The company generated $1,51,286 worth of Cam follower in one week with 20 operators. To calculate the labour productivity in terms of individual operator's contribution:

$$\text{Labour Productivity} = \frac{\$\ 1{,}51{,}286}{20}$$

= $ 7,564 per Employee per week (14)

which means each employee produces $ 7,564 for the company per week).

From equation (13) and (14), the labour productivity effects the cost. The cost per employee per week is increased when the labour is optimized. The same amount of production is done by 20 operators that produces more amount of cost. That ultimately reduction in cost benefits the organization.

Fig 7. Improved Layout in Witness with help of VSM

Fig 7.shows the total output per day of cam follower. Through the simulation it is seen that the production is 99 cam followers per day i.e. approximately 100 cam followers per day (that is same as the previous production rate). Also there is reduction in manpower from 13 to 10 operators per shift. Mainly the production rate remains same. Table III and Table IV shows the statistic report on manpower and machine respectively.

Table III: Manpower Requirement Statistic Report

Opx. No. -	ManPower	%Busy	%Idle	Avg. Job Time	No. of Jobs started	No. of Job Ended
OP 10	op1	100	0	60	874	873
OP 20, OP 30	op2	98.83	1.17	129.26	431	430
OP 30, OP 35	op3	52.36	47.64		1115	1114
OP 40, OP 50, OP 55	op4	62.69	37.31	76.22	467	466
OP 60	op5	95.21	4.79	129.9	417	416
OP 60	op6	91.36	8.64	110.31	471	470
OP 80, OP 90, OP 100, OP 120	op7	56.2	43.8	19.63	1626	1626
OP 110, OP 150, OP 160	op8	49.55	50.45	28.15	997	996
OP 130, OP 130	op9	53.02	46.98	147.63	204	204
OP 140	op10	47.4	52.6	271.94	99	99

TableIV: Statistic Report of Individual Machine

Opxn	% Idle	% Busy	% Blocked	% Cycle Wait Labor	No. Of Operations
OP10	0	100	0	0	873
OP20	14.88	32.48	0	52.64	41
OP30	66.14	30.9	0	2.96	130
OP30	34.3	65.06	0	0.64	389
OP35	7.71	20.79	35.74	35.76	492
OP40	48.92	45.57	0	5.5	258
OP50	48.34	43.26	0	8.41	91
OP55	74.55	23.12	0	2.33	13
OP60	8.25	91.49	0	0.26	472
OP60	5.18	94.82	0	0	414
OP70	94.9	5.1	0	0	414
OP80	55.79	22.7	0	21.51	314
OP90	68.97	22.08	0	8.95	209
OP100	79.55	11.09	0	9.36	105
Tank	0.57	14.18	81.59	3.67	33
OP110	48.3	18.19	2.92	30.59	303
OP120	68.74	16	0	15.25	303
OP130	89.99	4.01	0	6.01	99
OP130	47.71	52.29	0	0	99
OP140	52.6	47.06	0	0.34	99
OP150	92.27	2.96	0	4.76	99
OP160	65.36	32.95	0	1.69	98

The aim of the entire project is to reduce the manpower level without harming the production. Through simulating the assembly line, by giving the inputs and analysing the outputs, the manpower is reduced by 3 based on the busy and idle time statistics reports. This analysis was possible through the Witness Simulation Software.

D. Results of the end of optimization

Although the efficiency of time, monthly yield and manpower is higher, there are still imbalance of time. It needs to be continuously improved.For 56,800 seconds per day the production rate is same as the previous assembly line i.e. 100

cam followers per day. From the VSM, the further target is to improve the line to target 120 production per 2 shifts that is in-process. Through the optimization, it is seen that the man power can be optimised from 13 per shift to 10 per shift with the same production rate. Thus the target is achieved.

IV. CONCLUSION

The work carried out in this project was to optimize the man power requirement. By releasing 3 manpower per shift to other assembly lines, the company resources are used effectively. Hence, there is major cost saving to the organisation. Through the OEE calculations, the area in which there is need of improvement is determined. Different losses needs to be reduced to improve the efficiency of assembly line to meet World Class OEE factor. New line set up plan resulted intoreduction of major expensive assets and quality of the product is improved. Ultimately it gives profit to the company. In this paper, two methods are used that are Value stream mapping and Witness simulation. These two methods combined "completing each other" to improve the efficiency of Cam follower production line in Manufacturing Company. After VSM optimizing, month-yield is increased from 2,500 to 3,000. And then by witness optimizing, the yield remains 2,500. Work in progress to reach the target of 3,000 month-yield.

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