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Use of Facility Planning and Plant Layout with Work Study to Check the Balance of the Manufacturing Unit of Menon Pistons Ltd.

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***Abstract:* - Improving the quality of products being manufactured and enhancing the productivity is the utmost importance in today's global competition. This could be achieved by addressing the bottlenecks present in the manufacturing process as well in the layout. This project aims at optimizing the layout of piston manufacturing unit of menon piston limited Kolhapur. It is done by carrying out a detailed study to find out bottlenecks in the existing layout and suggest corrective measures to them. Various tools statistical quality control, flow process charts, flexsim software are used. The layout is optimized by first building and validating the simulation model of existing layout, followed by creating proposed layouts based on the various alternatives found for the bottlenecks and validating them. Alternatives or corrective measures are decided by making use of statistical tools like brainstorming and flowchart. Simulated results ate then compared with existing results so as to find the optimized layout. It is also intended to carry out the cost analysis so as to know the economic impact of implementation of proposed changes in the piston manufacturing unit.**

***Keywords* – Manufacturing layout, Simulation model, Flexsim**

I. INTRODUCTION

Menon Group which is one the largest Automotive Component manufacturers is situated in Kolhapur (which is about 400 Kilometres Southeast of Mumbai) have been the original Equipment suppliers of the most critical engine components like Aluminium Alloy Pistons, Piston Rings, Bimetallic Bearings, Bushes, Thrust Washers and large Complex Cast Iron Components like Cylinder Block and Cylinder Heads to major Automotive, Industrial Power Generation Engine/Vehicle manufacturers.

Menon Pistons Ltd (MPL) has been one of the leading manufacturers of critical/high precision Auto Components like Aluminium Alloy Pistons, Gudgeon Pins and Piston Rings for Passenger Cars (Diesel & Gasoline), Heavy and Light Commercial Vehicles, Heavy Duty Diesel Engines for Power Generation, Off Highway Vehicles, Compressors, etc.

- Heavy duty diesel engines for power generation/off highway vehicles/gas engines

1 mw piston 140 mm BEML piston Articulated piston

Fig 1: Pistons for heavy duty diesel engines

For Heavy Duty Diesel Engines for Power Generation/Off Highway Vehicle applications, MPL develop and produce Pistons with diameters ranging from 130 mm to 190 mm featuring Single Alfin and Dual Alfin Gravity Die Cast Pistons. MPL manufacture these Pistons on a dedicated manufacturing facility with special purpose CNC Machines to produce complex OD Profiles, and Pin bores with Oval Bore, trumpet bore or relief's as per the requirement.

II. STEPS OR PROCEDURE INVOLVED IN METHODS STUDY

1) Collection of Actual factory Data
2) Simulation modelling of current manufacturing activities for manufacturing facilities using suitable simulation software
3) Simulation of factory layouts for model validation.
4) Experimentation with various parameters affecting throughput.
5) Subsequent recommendation to company regarding various possibilities of lean manufacturing philosophy implementation and possible resultant improvements.

III. LAYOUT OF SHOP FLOOR

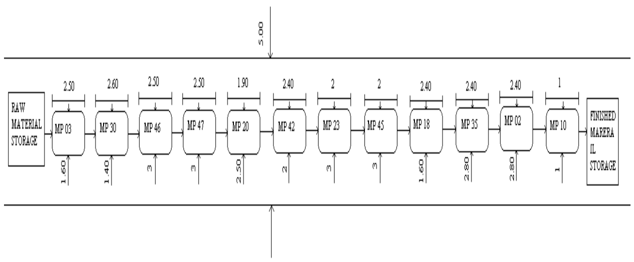

Fig. 2: Shop Layout

IV. DETAILS OF SHOP FLOOR

M/c no	Operation	M/c no	Operation
MP 03	Open end bore Rough bore Skirt turning	MP 23 & MP 45	1st groove 2nd groove 3rd groove Nickel ring turning Skirt chamfer & undercut
MP 30	S.F. Bore	MP18	Cam turning on skirt
MP 46 & MP 47	Top facing Counter Plunging Turning	MP35	Finish oval bore
MP 20	Rough dishing	MP02	Finish oval bore
MP 42	Finish dishing	MP10	Circlip

Table 1: Shop floor details

We have created a conceptual simulation model of the shop floor of Prasad Industries in FlexSim.

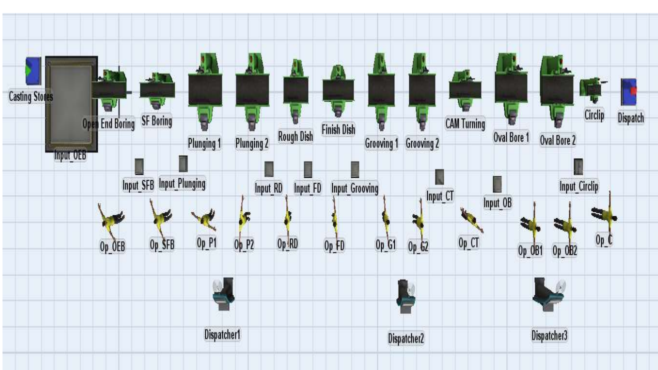

Fig. 3: Conceptual unconnected Simulation Model in FlexSim Software

In the above model we have covered all the possible elements and object of the shop floor of menon piston ltd. which necessary to carry out our simulation of this project. The actual operations being carried out on the floor need to be converted into equivalent and suitable objects so that they can be used in the software i.e. FlexSim.

V. PRELIMINARY DESIGN

After the conceptual model is ready, the system performance measures should be selected. The performance measures indicate the factors that are important or decisive in the net performance of the company. Out of all such factors, the factors that the team intends to vary should be decided as well as the levels of those factors that are to be investigated. After the factors are varied, the data that is to be extracted should be decided beforehand. Having the detailed plan at this early stage facilitates better understanding of the system and the system variables.

The process variables that we have chosen to vary are as follows

A. System output – System output is of the prime concern and the project will focus on maximizing the system output.
B. Machine utilization – It is imperative that the machines stay in the processing mode for as much time as possible.
C. Operator utilization – The operators should be busy for as much time as possible.

VI. INPUT DATA PREPARATION

To build any model, a vast amount of relevant data is needed to take the simulation as close to the real world scenario as possible. Our project involved the requirement of an extensive amount of such data and hence it was advisable to be very particular about the input data preparation. We proceeded with input data preparation in the following manner.

1) Understanding the process in general
2) Understanding the processes of each machine
3) Understanding the role of every operator
4) Understanding the roles of helpers
5) Breaking the processes in discrete measurable parts
6) Measuring the time taken by various activities using a stopwatch
7) Recording the time in tabular form as shown below

	Tool setting time		Piston setting time		Loading & Unloading time		Cycle time
Operation	Avg sec	Std dev	Avg sec	Std dev	Avg sec	Std dev	
Open bore	2904	8.33	7308	0.34	21.03	3.8	120
SF bore	2451	7.16	3708	8.94	16.13	3.01	60
Plunging 1	2916	6.2	4824	0.11	22.5	4.15	270
Plunging 2	3003	7.07	4932	0.1	21.66	3.84	270
Rough dish	1899	5.9	1764	3.77	20.13	3.94	45
Finish dish	1734	4.45	1815	4.65	23.26	5.51	84
Grooving 1	3633	11.8	7308	0.21	32.13	5.04	315.6
Grooving 2	3471	8.25	7164	0.21	30.26	4.38	315.6
Cam turning	1704	3.88	3618	7.78	21.43	4.07	84
Oval bore 1	1932	4.49	3795	9.47	19.93	3.94	90
Oval bore 2	1878	7.91	3690	6.7	18.96	3.16	90
Circlip	1296	3.26	3453	5.49	17.96	2	40

Table 2: Input Data Preparations Time Details

Model Translation in pictures is shown as below

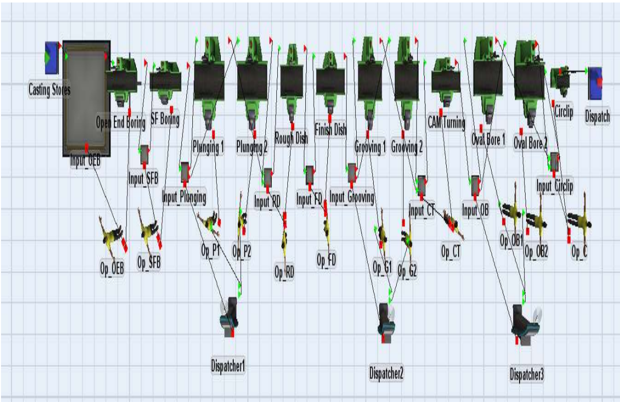

Fig 4: Conceptual connected Simulation Model in FlexSim Software

VII. VERIFICATION & VALIDATION

Before we experiment on or voice our opinions about the working of and improve the performance of any given manufacturing system, we have to make sure that we have a simulation model that represents the said system with considerable accuracy. For this, we have to compare the performances of the real world scenario and the simulation model. For this purpose, we use the deterministic model of the same to ensure that the model we built is definitely deterministic, we run the deterministic model for a single run of 453600 seconds and compare the throughput for each and every production run.

Model Run	System Output	Model Run	System Output
Run 1	1253	Run 6	1253
Run 2	1253	Run 7	1253
Run 3	1253	Run 8	1253
Run 4	1253	Run 9	1253
Run 5	1253	Run 10	1253

Table 3: Deterministic model- Trial Run

The Output of the real world was recorded for 5 weeks continuously; the output is shown in below table

Weeks	System Output
Week 1	1218
Week 2	1196
Week 3	1205
Week 4	1186
Week 5	1235
Average	1208

Table 4: Output of the production line in the real world

As can be seen from the readings, the behaviour of the simulated model is very close to the average performance of the real-world system, which shows that the simulation model we have modelled is considerably accurate and can be used as a basis for further experimentation

I. Stochastic model:

We have performed a production run of 10 test runs of stochastic models and the results of which are shown in the below table.

Model Run	System Output	Model Run	System Output
Run 1	1328	Run 6	1330
Run 2	1326	Run 7	1327
Run 3	1329	Run 8	1328
Run 4	1330	Run 9	1329
Run 5	1329	Run 10	1328
Average	**1328**		

Table 5: Stochastic Model-Trial Runs

As it can be seen from the above table, the output varies for every trial run and the average result of all trial runs is very close to the real-world system output.

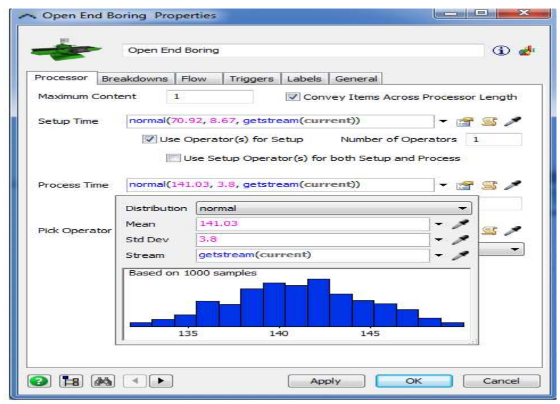

Figure 5: Normal distribution of cycle time for stochastic model

This model therefore can be used for the further experimentation to improve the system performance and to achieve the objectives of the study. Below is the statistical table of one of the production runs of the stochastic model.

First table shows the statistical run of machines.

Object	Processing %	Setup %	Blocked %	Schdown %	Waiting %
01_OEB	42.44%	21.35%	0.00%	33.33%	0.00%
02_SFB	22.91%	12.84%	0.00%	33.33%	0.00%
03_P1	43.95%	16.15%	0.00%	33.33%	0.00%
04_P2	43.86%	16.57%	0.00%	0.00%	0.00%
05_RD	19.56%	7.61%	0.00%	33.33%	0.00%
O6_FD	32.19%	7.40%	0.00%	33.33%	0.00%
07_G1	45.19%	19.78%	0.00%	33.33%	0.00%
08_G2	58.82%	25.10%	0.00%	0.00%	0.00%
09_CT	30.91%	10.78%	0.00%	33.33%	0.00%
10_OB1	16.11%	11.68%	0.00%	33.33%	0.00%
11_OB2	15.97%	11.35%	0.00%	0.00%	0.00%
12_C	16.97%	9.68%	0.00%	33.33%	0.00%

Table 6: Time Study for all the Machines

From this data, we can see that most of the machines are in schedule down condition it seems we have lots of scope into increase the productivity. We will do it in experiment trials. .

Below table shows the statistical run for operators

Object	% Utilize	% Idle	% Travel Empty	% Travel Loaded
Op_OEB	95.50%	0.00%	0.84%	0.84%
Op_SFB	49.10%	47.2%	0.82%	0.78%
Op_P1	90.70%	7.1%	0.60%	0.54%
Op_P2	60.45%	37.75%	0.61%	0.67%
Op_RD	42.20%	54.7%	0.73%	0.96%
Op_FD	57.40%	39%	0.71%	0.94%
Op_G1	98.31%	0.27%	0.47%	0.54%
Op_G2	83.93%	14.14%	0.63%	0.63%
Op_CT	61.70%	34.5%	1.02%	1.36%
OP_OB1	41.10%	56.7%	0.45%	0.74%
Op_OB2	27.32%	71.14%	0.46%	0.61%
Op_C	35.50%	58.8%	0.87%	1.16%

Table 7: Time Study for all the Operators

If we observe the statistics that all operators utilization ratio are under good range. Still operators of open end bore, and plunging machines have huge load which cases more fatigue. Hence we have to decrease it we will do it in experiment trails.

Below is the table showing the amount of unprocessed parts before and after every process at the end of the simulation run.

Object	Class	Maximum content
01_QIP_OEB_Max	Queue	0
02_QIP_SFB_Max	Queue	0
03_QIP_P1&2_Max	Queue	0
04_QIP_RD_Max	Queue	0
05_QIP_FD_Max	Queue	0
06_QIP_G1&2_Max	Queue	0
07_QIP_CT_Max	Queue	30
08_QIP_OB1&2_Max	Queue	0
09_QIP_C_Max	Queue	0

Table 8: Amount of unprocessed parts

As can be seen from these statistics, in the queues of cam turning are a major bottleneck, where the 30 jobs are pending & which confirms that there is an activity which takes up most of the time on the next machine as it starves for parts and remains idle.

VIII. EXPERIMENTATION

1) Experiment 1:

From the stochastic model results it seems that utilization of all machines are not 100%. Hence basic aim is to run all the machines in all three shifts and remove all breakdowns of the machines. In the company machine no 4, 8 & 11 (Plunging 2, Grooving 2 & Oval bore 2) are only three machines run in the third shift (night shift) and remaining machine kept off to equal all the loads of the machine but basic concept for increasing the productivity is all machines utilization more than 60%. Hence in the first experiment we remove all breakdowns and all machines run in all three shift. After modifications, the statistics of the system are as shown below

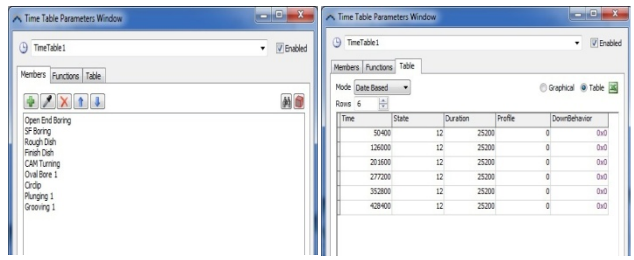

Fig 6: Simulation model of Experiment no. 1

System Output			
Run	Parts	Run	Parts
1	1780	6	1779
2	1780	7	1779
3	1781	8	1778
4	1780	9	1780
5	1779	10	1780
Average	1780		

Table 9: Experiment No. 1

Below are the performance measure statistics of machines for experiment 1

Object	Processing %	Setup %	Blocked %	Schdown %	Waiting %
01_OEB	62.17%	31.26%	0.00%	0.00%	0.00%
02_SFB	33.57%	18.33%	0.00%	0.00%	0.00%
03_P1	64.48%	23.69%	0.00%	0.00%	0.00%
04_P2	64.30%	24.30%	0.00%	0.00%	0.00%
05_RD	28.71%	11.20%	0.00%	0.00%	0.00%
O6_FD	47.29%	10.87%	0.00%	0.00%	0.00%
07_G1	67.93%	29.71%	0.00%	0.00%	0.0058%
08_G2	68.32%	29.17	0.00%	0.00%	0.0031%
09_CT	41.38%	14.45%	0.00%	0.00%	0.00%
10_OB1	21.58%	15.60%	0.00%	0.00%	0.00%
11_OB2	21.37%	15.18%	0.00%	0.00%	0.00%
12_C	22.73%	12.98%	0.00%	0.00%	0.00%

Table 10: Experiment 1- Machine Statistics

As can be seen from the table above, the utilization of all machine improved in this experiment. And there is load on both grooving and both plunging machines this can be improved we can do it in experiment no 2. And also increase all remaining machines utilization we have to decrease the load of plunging and grooving machines.

The report for time study of operators is given below.

Object	Utilize %	Idle %	Travel Empty %	Travel Loaded %
Op_OEB	93.44%	2.34%	1.23%	1.23%
Op_SFB	52.40%	43.84%	1.20%	1.14%
Op_P1	88.18%	9.39%	0.89%	0.80%
Op_P2	88.60%	8.76%	0.89%	0.99%
Op_RD	39.92%	56.35%	1.08%	1.41%
Op_FD	58.17%	38.10%	1.05%	1.38%
Op_G1	97.65%	0.22%	0.72%	0.82%
Op_G2	97.49%	0.27%	0.73%	0.73%
Op_CT	55.83%	39.81%	1.37%	1.82%
OP_OB1	37.18%	60.69%	0.61%	0.99%
Op_OB2	36.56%	61.38%	0.62%	0.82%
Op_C	35.71%	60.89%	1.17%	1.56%

Table 11: Experiment 1- Operators Statistics

The operator statistics have improved from the earlier model, where operators of plunging and grooving machine are now busy for almost 80% of the time and the operators on remaining machines are bit less busy as compared to previous state which can be an avenue to explore in our next experiment.

The queue statistics have been shown in the table below.

Object	Class	Maximum content
01_QIP_OEB_Max	Queue	0
02_QIP_SFB_Max	Queue	0
03_QIP_P1&2_Max	Queue	0
04_QIP_RD_Max	Queue	0
05_QIP_FD_Max	Queue	0
06_QIP_G1&2_Max	Queue	256
07_QIP_CT_Max	Queue	0
08_QIP_OB1&2_Max	Queue	0
09_QIP_C_Max	Queue	0

Table 12: Experiment 1- Queue Statistics

As can be seen from this table, the flow of material has also improved, as there are no evident bottlenecks in the system. The queue at the grooving machine has 256 items waiting to be processed, but that can be assigned to the fact that the system is always fed an amount of pistons which are above the capacity of the system.

Overall, the experiment improves the system in all the areas which we are monitoring as indicators of a good performance.

As stated earlier, the next experimentation should concentrate on further reduction in material movement.

2) Experiment no. 2

As explained earlier, this experiment will focus on decreasing the load of grooving machines. As can be seen from the layout, the longest material waited on the queue of grooving machine. Hence in this experiment, we will add another grooving machine with an operator to decrease the load of machine respectively.

This will also reduce the burden of the operators of grooving machine and also reduce the amount of fatigue they have to endure. Also, it will make the system more responsive as the production, running continuously.

The system after modifications is shown below

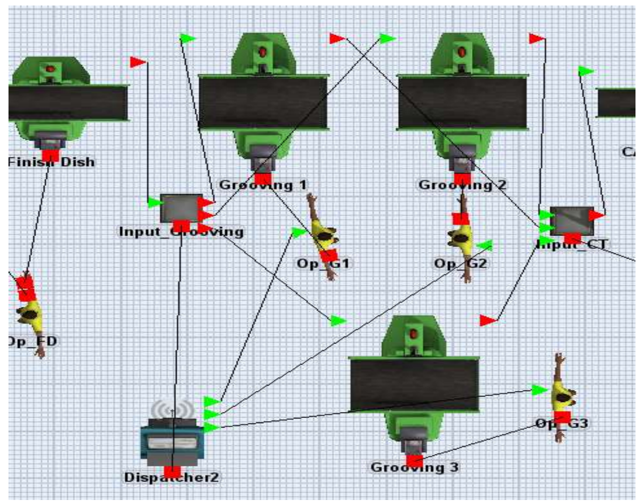

Fig 7: Simulation model of Experiment no. 2

After these modifications, the system output is as shown below.

System Output			
Run	Percentage	Run	Percentage
1	2039	6	2042
2	2038	7	2041
3	2042	8	2039
4	2541	9	2042
5	2040	10	2029
Average	2040		

Table 13: Experiment 2- Trial Runs

Below is the table for statistics of machines:

Object	Processing %	Setup %	Blocked %	Schdown %	Waiting %
01_OEB	63.66%	32.02%	0.00%	0.00%	0.00%
02_SFB	34.36%	19.29%	0.00%	0.00%	0.00%
03_P1	65.98%	24.26%	0.00%	0.00%	0.00%
04_P2	65.76%	24.86%	0.00%	0.00%	0.00%
05_RD	29.36%	11.45%	0.00%	0.00%	0.00%
O6_FD	48.34%	11.22%	0.00%	0.00%	0.00%
07_G1	52.22%	22.84%	0.00%	0.00%	0.0026%
08_G2	51.92%	22.16%	0.00%	0.00%	0.0018%
13_G3	52.16%	22.81%	0.00%	0.00%	0.00%
09_CT	47.42%	16.56%	0.00%	0.00%	0.00%
10_OB1	24.73%	17.88%	0.00%	0.00%	0.00%
11_OB2	24.50%	17.40%	0.00%	0.00%	0.00%
12_C	26.05%	14.86%	0.00%	0.00%	0.00%

Table 14: Experiment 2- Machine Statistics

The statistics shows that, the load of grooving machines is equally divided into three machines and the operator utilization also equally divide hence this system is more productive and stable.

However, the rest of the machines are busy for a time that is within the acceptable range which means, that the operators on these machines are free for an acceptable time.

The time study for various operators in the system is shown in the table below.

Object	Utilize %	Idle %	Travel Empty %	Travel Loaded %
Op_OEB	95.68%	0.00%	1.26%	1.26%
Op_SFB	53.65%	42.50%	1.23%	1.17%
Op_P1	90.24%	7.28%	0.91%	0.82%
Op_P2	90.63%	6.67%	0.91%	1.01%
Op_RD	40.82%	55.37%	1.10%	1.44%
Op_FD	59.46%	36.72%	1.08%	1.41%
Op_G1	75.06%	23.30%	0.55%	0.63%
Op_G2	74.09%	24.21%	0.55%	0.55%
Op_G3	74.92%	23.34%	0.55%	0.64%
Op_CT	63.99%	31.02%	1.57%	2.09%
OP_OB1	42.62%	54.95%	0.70%	1.13%
Op_OB2	41.85%	55.74%	0.71%	0.94%
Op_C	40.87%	55.19%	1.34%	1.79%

Table 15: Experiment 2- Operators Statistics

As we can see the utilize table in the experiment no 2 chart we will see the load on operator of OEB, P1 and P2 are tremendously increase so we have to add another operator in that area to reduce the fatigue of previous operator this will we do in the 3rd experiment

The statistics of various queues are shown in the table below.

Object	Class	Maximum content
01_QIP_OEB_Max	Queue	0
02_QIP_SFB_Max	Queue	0
03_QIP_P1&2_Max	Queue	0
04_QIP_RD_Max	Queue	0
05_QIP_FD_Max	Queue	0
06_QIP_G1&2_Max	Queue	0
07_QIP_CT_Max	Queue	0
08_QIP_OB1&2_Max	Queue	0
09_QIP_C_Max	Queue	0

Table 16: Experiment 2- Queue Statistics

The queues show that, there are no evident bottlenecks that can hamper the performance of the system; however, our next improvements will focus on reducing the burden of the operators working on open end bore and plunging machines, which might also increase the output further.

3) Experiment No. 3

As said earlier, this experiment will focus on reducing the burden of the operators working on open end bore and both plunging machines. Here, we shall assign one operator for this machines respectively and assigns equally tasks to a both operators.

After these modifications are carried out, the system is as shown below.

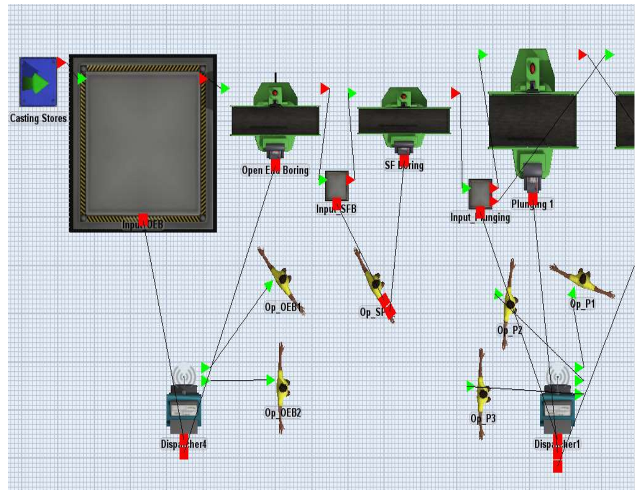

Fig 8: Simulation model of Experiment no. 3

After these modifications are carried out, the output of the system is as shown in the table below

System Throughput			
Run	Percentage	Run	Percentage
1	2073	6	2075
2	2077	7	2077
3	2076	8	2073
4	2073	9	2075
5	2074	10	2076
Average	2074		

Table 17: Experiment 3- Trial Runs

The time study for machines is shown below

Object	Processing %	Setup %	Blocked %	Schdown %	Waiting %
01_OEB	64.76%	32.57%	0.00%	0.00%	0.65%
02_SFB	34.95%	19.62%	0.00%	0.00%	0.00%
03_P1	67.12%	24.67%	0.00%	0.00%	0.73%
04_P2	66.89%	25.30%	0.00%	0.00%	0.41%
05_RD	29.87%	11.64%	0.00%	0.00%	0.00%
O6_FD	49.14%	11.31%	0.00%	0.00%	0.00%
07_G1	53.11%	23.23%	0.00%	0.00%	0.0026%
08_G2	52.81%	22.54%	0.00%	0.00%	0.0018%
13_G3	53.06%	23.20%	0.00%	0.00%	0.00%
09_CT	48.24%	16.84%	0.00%	0.00%	0.00%
10_OB1	25.15%	18.19%	0.00%	0.00%	0.00%
11_OB2	24.92%	17.71%	0.00%	0.00%	0.00%
12_C	26.50%	15.12%	0.00%	0.00%	0.00%

Table 18: Experiment 3- Machine Statistics

As can be seen from the machine statistics, all machine are equally utilize and that can be into acceptable range

The operator's statistics are given in the table below.

Object	Utilize %	Idle %	Travel Empty %	Travel Loaded %
Op_OEB1	32.54%	65.50%	0.65%	0.56%
Op_OEB2	42.57%	54.97%	0.72%	0.96%
Op_SFB	54.57%	41.51%	1.25%	1.19%
Op_P1	64.81%	33.34%	1.03%	0.58%
Op_P2	59.34%	38.71%	1.11%	0.59%
Op_P3	59.84%	38.31%	1.06%	0.03%
Op_RD	41.52%	54.60%	1.12%	1.47%
Op_FD	60.49%	36.63%	1.10%	1.43%
Op_G1	76.35%	21.98%	0.56%	0.64%
Op_G2	75.35%	22.92%	0.56%	0.56%
Op_G3	76.27%	22.01%	0.56%	0.65%
Op_CT	65.09%	29.84%	1.59%	2.12%
OP_OB1	43.34%	54.18%	0.71%	1.15%
Op_OB2	42.57%	54.97%	0.72%	0.96%
Op_C	41.63%	54.42%	1.36%	1.82%

Table 19: Experiment 3- Operators Statistics

As can be seen here, performed modifications have reduced the burden of these workers making their workload manageable.

The queue statistics are given in the table below

Object	Class	Maximum content
01_QIP_OEB_Max	Queue	0
02_QIP_SFB_Max	Queue	0
03_QIP_P1&2_Max	Queue	0
04_QIP_RD_Max	Queue	0
05_QIP_FD_Max	Queue	0
06_QIP_G1&2_Max	Queue	0
07_QIP_CT_Max	Queue	0
08_QIP_OB1&2_Max	Queue	0
09_QIP_C_Max	Queue	0

Table 20: Experiment 3- Queue Statistics

The queues show that, there are no evident bottlenecks that can hamper the performance of the system.

IX. RESULT & DISCUSSION

1) Experiment 1

As it can be seen from the system output table above, the output of the system has improved drastically. The improvement in productivity is,

$$Increase\ in\ Productivity = \frac{Improved\ Average\ Output - Earlier\ Average\ Output}{Earlier\ Average\ Output}$$

$$= \frac{1779 \quad - \quad 1328}{1328}$$

$$= 33.96\ \%$$

2) Experiment 2

As it can be seen from the system output table above, the output of the system has improved drastically. The improvement in productivity is,

$$Increase\ in\ Productivity = \frac{Improved\ Average\ Output - Earlier\ Average\ Output}{Earlier\ Average\ Output}$$

$$= \frac{2040 \quad - \quad 1779}{1780}$$

$$= 14.67\ \%$$

3) Experiment 3

As it can be seen from the system output table above, the output of the system has improved drastically. The improvement in productivity is,

$$Increase\ in\ Productivity = \frac{Improved\ Average\ Output - Earlier\ Average\ Output}{Earlier\ Average\ Output}$$

$$= \frac{2074 \quad - \quad 2040}{2040}$$

$$= 1.66\%$$

X. CONCLUSION

As per the goals set at the initial stage, we have taken the system through the entire simulation process to increase the productivity of the system at minimum expenditure.

The total improvement in productivity earned over these experimentations can be given by,

$$Total\ Increase\ in\ Productivity = \frac{Final\ Improved\ Average\ Output - Initial\ Average\ Output}{Initial\ Average\ Output}$$

$$= \frac{2074 \quad - \quad 1277}{1277}$$

$$= 62.41\%$$

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