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PRODUCTION CAPACITY ANALYSIS OF A SHOCK ABSORBER ASSEMBLY LINE USING SIMULATION

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ABSTRACT

This paper reports findings of a study of shock absorber assembly line using computer simulation. The shock absorber assembly line feeds shockers to the motorcycle assembly line. The assembly line simulated in this project is located at an OEM for Bajaj Auto Ltd., the largest producers of scooters and motorcycles in India. In this paper, results of simulation are presented from two scenarios. The first is the original layout of the system. The second simulation is the suggested modifications. Data was gathered and evaluated to determine the necessary parameters to be used. The new demand required the OEM to increase its capacity by 200 shock absorbers per day. After implementing the proposed model the daily output increased by 435 shock absorbers. The highlights of our analysis was that this increase in production rate was achieved without any increase in direct labor, contributing to a gross increase in profit by 32%

1 INTRODUCTION

As the twenty first century begins, the global marketplace continues to grow stronger. To stay competitive, companies need to make long as well as short-term capacity decision with proper planning. This paper documents such a simulation study in a shock absorber assembly line. The assembly includes 14 operations. Among these, the piston rod subassembly and the spring fitting operations are critical to the assembly process. The piston rods assembled at the stations, along with the base valve assembly are combined with the inner tube and the outer tube to form a basic damper. After testing for its damping force, the damper is fitted with bush, adjuster, spring and eyelets. The finished shock absorber is inspected for its center-to-center distance before it is packed at the packing station. The preliminary study at the plant revealed the following characteristics, which were the basis for achieving the desired objective:

- From time study analysis, it was found that the damping force testing machine required higher setup time
- The piston rod sub-assembly was found to be a bottleneck due to large amount of parts being assembled (Roser et. al 2003)
- The spring fitting operation was considered a critical process due to its larger process time
- The loading and transferring of finished shock absorber from packing station to loading zone was done manually, which did not comply with the ILO standards
- No specific schedules were prepared for preventive maintenance nor were any specific efforts made for analyzing each fault. The time consumed and the frequency of each fault was not studied.

Thus, the production rate is not adequate to the daily demand, leaving subsequent gap between daily demand and the production rate. Production capacity can be increased in numerous ways, such as reduction in process time, addition, allocation and/or proper utilization of resources. Thus the objective of this study is to propose an alternate layout to the current assembly line that could increase the capacity to 1200 parts from the current 1000 parts per day.

2 DATA COLLECTION

Necessary data were collected by conducting time and work-study at every workstation. The current layout runs for 3 shifts a day, 6 days a week. At each station ten sample values for operation time were collected. Since the sample size was small ($n < 30$), we could not determine the distribution followed by the data. We will assume that the data follows a log normal-distribution. The numbers used to formulate the model are averages of ten sample times recorded. These average times have been tabulated below.

3 PRODUCT DESCRIPTION

The plant manufactures a large variety of shock absorbers for Bajaj Auto Ltd. Bajaj Auto Ltd. makes a large variety of vehicles for the Indian and the South East Asian market.

Table 1: Process Times in Seconds

No.	Operation	(Time, Std. Dev.)
1	Piston Rod Assembly	L (5, 1)
2	Base Valve Assembly	L (3 1)
3	Inner Tube Assembly	L (1, 0.75)
4	Outer Tube Assembly	L (1, 0.75)
5	Oil Filling Process	L (3, 0.75)
6	Pneumatic Pressing	L (2, 1)
7	Inspection at Station #1	L (3, 1)
8	Sealing	L (1, 0.5)
9	Bush Fitting	L (2, 1)
10	Spring Seat & Adjuster Assembly	L (2, 1)
11	Nut Fitting	L (2, 1)
12	Spring Fitting	L (3, 1)
13	Inspection at Station # 2	L (3, 1)
14	Cleaning	L (2, 1)

Thus the shock absorbers tend to be of different specifications depending upon the vehicle it is to be assembled onto. One of the shock absorbers BS1056 is shown below in Figure 1.

Figure 1: BS1056 Shock Absorber

These shock absorbers are used in Bajaj's spearhead model Pulsar. The company makes four kinds of shock absorbers differentiated depending upon the following specifications.

- Center-to-Center Distance (220 mm)
- Diameter of top Eyelet (12 mm)
- Diameter of bottom Eyelet (16 mm)
- Spring seat to bottom end distance (65mm)

All the parts going into making the four shock absorbers are the same with same time amount of times required for every model of shock absorber. The only differentiating characteristics are the four parameter stated above.

4 SYSTEM DESCRIPTION

The assembly line at the plant can be best described as a transfer line producing shock absorbers of different specifications for two-wheelers. The same assembly line is used to make different classes of shock absorbers depending upon the orders coming in from Bajaj Auto Ltd.

The assembly line starts with simultaneous sub assemblies of piston rod and the base valve. They are pre assembled at two separate stations before they are introduced into the main assembly line. The piston rod assembly is the most critical sub assembly in the shock absorber. It starts with inserting a pre-lubricated oil seal, rebound spring and rod guide onto the piston rod. Later a spring valve, orifice valve, bush, plate valve and a nylon nut are assembled in that order. The components of the piston rod assembly are shown in Figure 2:

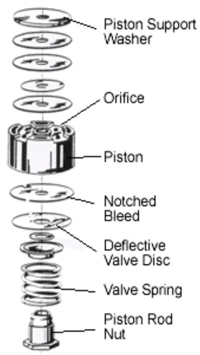

Figure 2: Piston Rod Assembly

The base valve assembly starts with inserting the plate valve, spring valve and orifice valve over a base valve case. These three parts are pressed together using a pneumatic press to produce the base valve subassembly. This subassembly is then press fitted onto a ball passed and cleaned inner tube. The inner tube is then manually inserted into the outer tube. Here preset amount of oil is filled in the tube depending upon the damping force characteristics required. After oil filling, the piston rod subassembly is manually inserted into the outer tube subassembly using a thimble to ease and speed up the process. This assembly is then pneumatically pressed to form the damper.

This unsealed damper is then taken to the servo hydraulic machine where a 100% inspection occurs to check for the damping force at different velocities. Any rejects are disassembled and re-fed into the system for reuse.

The unsealed dampers move over a constant speed conveyer to the sealing machine. These dampers move on to the bush-fitting machine where the bottom center of the damper is bushed. Before leaving the bush-fitting machine a spring adjuster and a spring seat are inserted in the damper. At the same time the threaded end of the piston rod is fitted with a nut. The dampers move on to the spring fitting machine where a dust cover and pre-assembled top eyelet are used in conjunction with a spring to complete the whole shock absorber assembly. The shock absorber is then inspected for its top to bottom center distance. It is then cleaned with pressurized air and packed in boxes of 12. The Process Flow Diagram is shown in Figure 3.

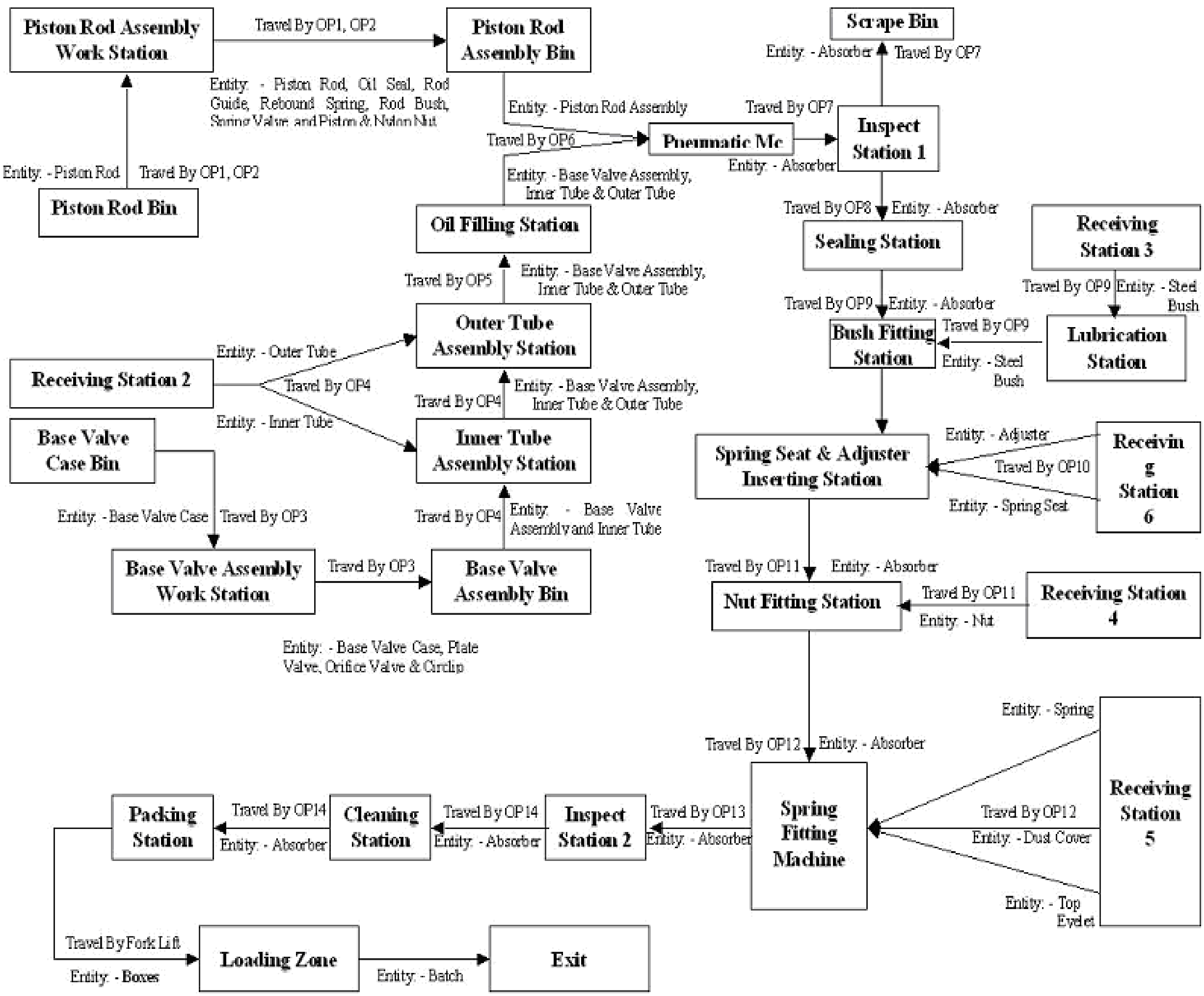

Figure 3: Process Flow Chart

5 MODEL TRANSLATION

5.1 Model Scenarios

The shock absorber assembly line simulation was run twice. First it was run to simulate the original assembly line at the plant. Later a modified proposed layout was run to study the effectiveness of the proposed model. Output data for both the scenarios were compared to justify the effectiveness of the proposed layout. In each case the model was run with a 30 minute warm-up, to eliminate the start up transients, allowing the system to fill up the bins, thus reaching steady state operation. This makes the model more realistic, since the factory starts each day, with shock absorbers remaining in the system from the prior shift. After the warm-up period, the models were run for twenty-four hours (three shift).Two 15-minute breaks and one 30-minute lunch break are incorporated into the system using the shift command provided in ProModel. Section 7.0 explains the reasons for determining 30 minutes as the warm up period.

5.2 Model Assumptions

The current production rate is 1000 parts per day. The daily demand has increased to 1200 parts per day. Thus, production rate must be increased by 200 parts per day.

We made the following assumptions in our models:

- Raw material at different receiving stations follow a continuous ordering and delivery system
- No machine downtime has been considered.
- There are two 15 minute coffee breaks and one 30 minute Lunch Break in each shift
- There was no shortfall in the entity arrivals at any arrival station
- Changes in the piston rod assembly will subsequently change the production quantity by relatively equal amount
- Manufacturing of piston rod subassembly and base valve subassembly does not cause delay in the manufacturing of other subassemblies and vice versa

- Each subcontracted part like the inner tube, outer tube etc. are readily available at respective stations when required
- Factory layout and the flow of products remained unchanged
- Capacity of conveyers is infinite and has a constant speed. All the conveyers were of accumulating type
- Operators work at their full efficiency
- In the location table, the rule oldest by priority and first in, first out is assumed
- The rejects at the damping force testing machine is considered as scrap and the rework operation is not taken care by the model.

5.3 Proposed Layout

The following changes were made to the current model:

- Two piston rod subassembly stations were added in place of one in the current layout
- Number of workers remain the same but have been moved around to different stations
- Originally there were two operators working at the packing station. One of the operator will be moved to another station and will be replaced by a Forklift
- Two operators will work at the spring fitting machine instead of one
- A spring fitting machine will be added to the proposed layout

5.4 Model Development

In all there are 62 locations, 31 entities, 9 conveyors each having length of 30 feet and speed of 120 ft/min. 16 operators are used at various location and a fork lift is utilized to transfer the packed boxes from packing station to loading zone. Four variables were also used to keep track of the number of part output at four critical locations.

6 VERIFICATION

The model of the manufacturing facility was verified by conducting the following tasks (Bowden et al 2000)

- “Dummy variables” were used in the model to track the movement of entities at various locations. This technique was particularly useful during the coding of the “GROUP” statement at various assembly locations. The variables were deleted after the process verification
- Animation was used to aid in the visualization of entity flow paths. This technique made it possible to ensure that entities were traveling in accordance with the entity flow diagram. Colors were used for easier visual tracking of entity flow. In the end they were removed from the model to increase the speed of simulation
- The trace command was used to verify that the entity flow logic, resource operations, and designed path networks simulated the system processes as intended. The step trace command allowed for proper tracking of the entity arrivals from the receiving locations, the movement of entities along designated path networks with proper move times and the appropriate process events.

Discrepancies in model logic discovered during the verification process were subsequently rectified.

7 VALIDATION

The model of the manufacturing facility was validated by conducting the following tasks:
The animation and trace techniques were applied to the model verification process to ensure proper model execution.

A sensitivity analysis was performed to determine the effects of entity arrivals and manpower on the model output.(Gupta 2003) This analysis was included in the calibration process to represent current model conditions by adjusting the capacity (manpower) of the various locations so that the shock absorber production rate was 1093 shock absorbers per day. The actual daily production was 1000 shockers per day. The results are well within the typical variation limits between the model and the system performance. Typically 5 – 10 % difference is attributed to random variation.

A warm-up period was determined to model the transient phase of the system. Adequate amount of warm-up period is essential in order to consider corresponding output from the model. The warm-up period was determined by running the model for 24 days 24-hour per day and graphically (output versus time) determining the warm-up period. This analysis was conducted for the current operating condition and for the proposed case. The warm-up period for both the cases was determined to be 2.4 minutes. But we have used 30 minute as the warm up period in order to prevent any variants that we might have not considered, from affecting the model.

We have not been able to validate the simulation results with the actual results from the company so far.

8 COST ANALYSIS AND RESULTS

Before starting the cost analysis it is important to note the following points

- The number of operators used in the current layout is same as the number of operators used in the proposed layout but with different allocations. The operators are waged on hourly basis and are paid $ 0.45 per hour (Actual Values in Indian Rupees)

- There is one piston rod assembly station in the current layout. As the piston rod assembly is a major process taking maximum amount of time, it is suggested in the proposed layout to setup another piston rod assembly. The total cost of setting another Piston rod assembly station is calculated to be $ 600
- The spring fitting machine was also found to be a bottleneck in the assembly line. The only option left was to increase their units so as to speedup up the total operation. The market survey for the cost of the spring fitting machine was found to be $ 9000
- At the Loading station, the boxes from packing station were transferred to the loading dock by means of two operators. It was logically feasible to use a forklift in place of an operator so as to speedup the loading operation. The cost of a forklift was found out to be $1250.

Thus incorporating the above-mentioned changes in the proposed layout, the total revenue required was estimated to be as follows

Total setup cost for the proposed layout
= 600 + 9000 + 1250
= $10,850

The selling price of each shock absorber was = $5.68 each.
Output for the current assembly line is = 1093/day.
Output for the proposed assembly line = 1435/day.

It costs the company $ 0.09 for each hour the part spend in processing in the manufacturing shop. The profit per Item is $ 0.96 after deduction the direct material cost and all other overheads.

After performing the required calculations, the daily profits from the current layout were $1049.28 and that of the proposed layout will be $1377.60. Increase in profit was 32%. The setup cost that would be incurred by OEM would be $10,850. The change in total net profit is $328.32. Thus the payback on the setup cost is approximately one month. All the values reported are before tax values. Also depreciation is not taken into consideration while performing this analysis.

The cost analysis seems to suggest that the proposed layout is feasible. Also the profit earned is adequate to give the project a go ahead. The summary of important results is tabulated below.

Table 2: Results of the Cost Analysis

	Current	Proposed
No. Of Operators	16	16
Avg. % Utilization of Operators (16)	24.8	55.8
Daily Production	1093	1435
Avg. time Entities blocked in system (min.)	92.23	62.41

After reviewing all the results our suggestion would be to implement the proposed layout.

9 CONCLUSION

The daily production requirement of the company has increased from 1000 shock absorbers per day to 1200 shock absorbers per day. The proposed suggestion does increase the production capacity to 1435 parts per day, which is much higher than the required efficiency. Secondly no operators had to be hired or laid off in order to implement the system. The operator efficiency in the proposed layout is more than twice of the current layout. Thirdly, amount of time the parts stay in system has reduced drastically. This reduces the WIP as well as the chances of rejects due to breakage.

We suggest that the human resources might be looked into as the area to further improve the capacity of the system, since some operators work at a very low productivity level.

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