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PRODUCTIVITY ENHANCEMENT THROUGH SIMULATION AND QUEUING NETWORK ANALYSIS

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ABSTRACT

This paper presents results from a research project dealing with the search and investigation of opportunities for productivity improvement at a manufacturing concern involved in fabrication and assembly operations. A SLAM II simulation model was developed to assess the material flow problems and the storage capacity of the system. A queuing network analysis for an automated serial assembly line was also performed using MANUPLAN due to insufficient time and scarcity of accurate production data. Results from the study outline the steps required to improve productivity.

1 INTRODUCTION

The objective of this study was to determine opportunities for productivity enhancement at a manufacturing concern involved in fabrication and assembly operations. The particular areas of concentration were the automated inner door assembly area and flow of inner doors via the power and free conveyor to the final assembly lines 1, 2, and 3 (Figure 1).

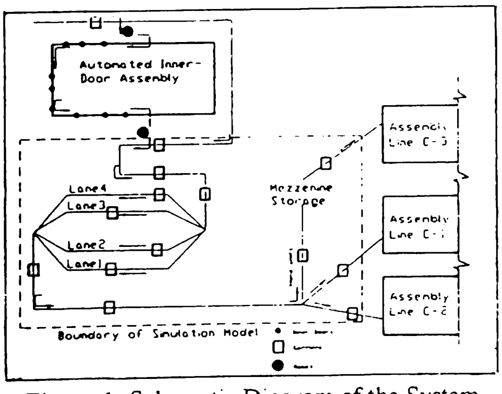

Figure 1: Schematic Diagram of the System

Inner doors assembled on the line were loaded on carriers which were transported to an overhead 4-lane storage area. Each lane accommodates upto 28 carriers. The power and free conveyors supplied the carriers to the final assembly lines as needed.

It was discovered that the output of the three assembly lines together was about 6700 dishwashers per day, whereas the automated inner door line produced only about 6000 doors per day. Consequently, a separate manual inner door line was constructed on the mezzanine to produce the remaining 700 - 900 doors per day. It was also found that the power and free conveyors did not directly supply doors to line 3. Inner doors were offloaded from lines 1 and 2 onto a Wilcox conveyor during the third shift and stored for use during the first shift on line 3. Such an operation was inefficient, since it involved double handling of inner doors.

These problems were presented and discussed with the management. If the double handling was to be eliminated, the existing power and free conveyor system had to be re-routed to supply doors directly to line 3. This would require an increase in production rate of the automated door line. It was possible that such a system would require additional storage lanes to be added to the existing power and free conveyor system to store the increased number of doors and to provide a buffer against possible breakdown in the door assembly. Thus it was decided to concentrate all efforts on the power and free conveyor and automated inner door line during the subsequent phases of the project.

2 ANALYSIS OF STORAGE LANES

SLAM II simulation models (Pritsker, 1986) were developed to assess the material flow problems and the storage capacity of the system.

2.1 Assumptions

The assumptions made in the process of developing the computer model are listed below (Jamaldin, 1994):

1. The carriers were assumed to select overhead storage lanes in a fixed order.
2. The selection of carriers from overhead storage for assembly lines was based on FIRST-IN-FIRST-OUT (FIFO) rule.
3. Breakdown and stoppage of the door line was estimated to be about 30% based on actual observations.

2.2 Analysis of Results

Various system scenarios were explored by varying the following parameters:

1. Number of overhead storage lanes.
2. Rate at which carriers leave overhead storage for assembly.
3. Breakdown rate of the automated inner door line.

Simulation analysis performed on a model representing the existing system indicated an average throughput of 6142 inner doors per day and about 28 carrier spaces remain unused. These numbers match the behavior of the actual system and hence validates our simulation model.

The simulation program was modified to determine the effects of increasing the number of storage lanes from 4 to 6. The breakdown rate of the automated door line and the rate at which the carriers leave for assembly were both varied. As can be seen from Table 1, the maximum average throughput attained was about 6409 doors per day. This represents a 5% improvement from the existing model.

Table 1: Effect of Increasing the Number of Storage Lanes

Breakdown Rate (%)	No. of Lanes	Rate of Carrier Departure (min/carrier)	Throughput (Inner Doors per Day)
30*	4*	5.6*	6142*
30	6	5.6	6142
25	6	5.6	full
25	6	5.3	6409
20	6	5.3	full

* : Existing System

Based on these results and given the existing system parameters, it was evident that an addition to the existing four overhead storage lanes would not improve the overall throughput.

The simulation model was then modified to determine the effects of varying the breakdown and carrier departure rate, while the number of storage lanes was kept constant at four. The results (Table 2)

Table 2: Effect of Varying Other System Parameters

Breakdown Rate (%)	No. of Lanes	Rate of Carrier Departure (min/carrier)	Throughput (Inner Doors per Day)
30*	4*	5.6*	6142*
30	4	5.0	6175
30	4	4.7	6168
25	4	4.7	6148
20	4	4.7	6683
14	4	4.7	7079
9	4	4.7	full

* : Existing System

show that given the breakdown rate at 30%, increasing the demand of doors does not significantly impact throughput. However, if the departure rate for the carriers was kept constant at 4.7 min. per carrier, and breakdown rates were decreased from 30% to 9%, the throughput increases significantly (Figure 2). Thus it can be concluded that with 14% average breakdown rate, 4.7 min. average carrier departure, and 4 overhead storage lane system, an average throughput of about 7079 inner doors was feasible. This could provide sufficient number of inner doors to supply line 3, thereby help minimize the double handling problem.

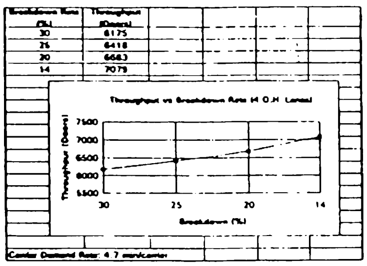

Figure 2: Effect of Breakdown Rate on Throughput

3 ANALYSIS OF AUTOMATED INNER DOOR LINE

The problem now was to determine whether the breakdown rate of the automated inner door line (Figure 3) could be reduced. Actual production data obtained demonstrated that the automated door line remained the down for 30% of the total time. It was also found that

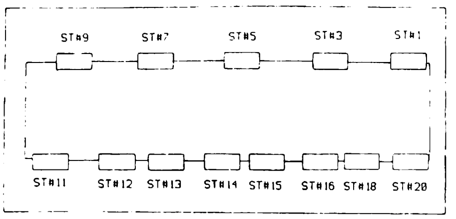

Figure 3: Schematic Diagram of Automated Door Line

station numbers 1, 11, 15, 16, and 18 undergo frequent failures and account for 85% of the total downtime of the door line (Figure 4).

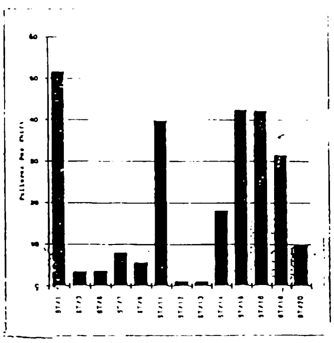

Figure 4: Number of Failures per Shift for Stations in Door Line

3.1 Models Description

Due to insufficient time and scarcity of accurate production data, it was decided not to perform a detailed simulation analysis on the automated inner door line (Suri and Diehl, 1985). Instead a rough-cut analysis was carried out using MANUPLAN - queuing theory based simulation tool. In order to explore various production control strategies, various scenarios were simulated using MANUPLAN:

1. Base Case Model - The base model run was performed using average MTTF values gathered from the production reports. The main objective was to estimate approximate values of MTTF at each station under which the existing system was performing. This objective was attained by performing several iterations of the MANUPLAN model by increasing MTTF values. Model validation was performed by comparing the model output with the actual average output of the line. Actual observed values of operation time per station were used and maximum machine utilization was assumed to be 70%.
2. Scenario A - The MTTF values of the individual machines were increased by 20%. Also the operation time of station #14 was reduced to 10 sec.
3. Scenario B - The MTTF values of the machines were further increased and the maximum machine utilization was increased to 85%.

3.2 Assumptions

The main assumptions of the above models were:

1. All the stations had deterministic fixed operating times with negligible variance and set-up times.
2. System throughput and utilization factors of individual stations were used as performance measures.
3. Line was assumed to have infinite inter-stage buffer space.
4. Traveling time between the stations was ignored.

3.3 Analysis

The results obtained from MANUPLAN are listed in Tables 3 to 5.

From Table 3 it can be observed that the target output of 1500 doors per shift can not be achieved. The utilization of station #14 with a processing time of 14 sec. was 73.7%. Thus it may cause bottleneck in the line. It should also be noted that the actual production achieved by the line was 1800 doors per shift. This discrepancy between the basecase model and the actual results can be attributed to the scarcity of accurate MTTF and MTTR data, as well as to the wide variations in the observed MTTF data. However, this model gives a starting point for subsequent analysis.

Table 3: Summary of Results of Basecase Manuplan Run

Station #	Operation Time (in secs)	Total Utilization (%)	Station #	Operation Time (in secs)	Total Utilization (%)
1	8	47.6	13	5	26.1
3	6	31.4	14	14	73.7
5	10	52.4	15	10	53.9
7	8	42.3	16	10	53.9
9	8	41.8	18	10	55.2
11	8	44	20	10	53
12	8	41.8			
Total Production Achieved = 1500					

The scenario A model was run with increased MTTF values to achieve a target production of 1900 doors per shift. The operation time of station #14 was reduced to 10 sec. The results indicate that the average utilization of the stations increased significantly and the desired production could be achieved (Table 4).

In scenario B the MTTF values were further increased, and the target utilization was increased to 80%. This was done to represent the changes in the

Table 4: Summary of Results of Scenario A Manuplan Run

Station #	Operation Time (in secs)	Total Utilization (%)	Station #	Operation Time (in secs)	Total Utilization (%)
1	8	59.00	13	5	33.03
3	6	39.70	14	10	66.50
5	10	66.30	15	10	67.90
7	8	53.50	16	10	67.90
9	8	52.90	18	10	69.28
11	8	55.20	20	10	66.90
12	8	52.90			
Total Production Achieved = 1900					

system output on upgrading some of the stations. Average throughput of the line was increased to 2300 doors per shift (Table 5). The average utilization of the individual machines also increased. This model demonstrated that with proper upgrade and maintenance of the machines the output of the line could be increased significantly.

Table 5: Summary of Results of Scenario B Manuplan Run

Station #	Operation Time (in secs)	Total Utilization (%)	Station #	Operation Time (in secs)	Total Utilization (%)
1	8	67.2	13	5	39.9
3	6	48.1	14	14	80.6
5	10	80.3	15	10	82.27
7	8	64.76	16	10	82.28
9	8	64.07	18	10	83.87
11	8	66.82	20	10	84.07
12	8	64.1			
Total Production Achieved = 2300					

4 CONCLUSIONS

The following observations could be made about the system under study:

1. Increasing the number of storage lanes from 4 to 6 would not improve the system performance and was thus not warranted.
2. Breakdown rate of the automated inner door line had a significant effect on throughput.
3. Increasing the carrier departure rate did not increase throughput significantly.
4. There existed opportunities for reducing the breakdown rate of the automated door line by proper maintenance and upgradation of some of the machines.
5. If the breakdown rate of the automated door line could be reduced, it could supply doors to all the 3 assembly lines, thus eliminating the needs of the manual door line.

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