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SIMULATION MODELING AND ANALYSIS OF A NEW MIXED MODEL PRODUCTION LINES

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ABSTRACT

Mixed model production lines are often used in manufacturing systems. In production lines, different product types are simultaneously manufactured by processing small batches. This paper describes a recently completed project involving the development of simulation models for a mixed model production line in a refrigerator company. Decision maker wants to determine the bottlenecks before changing the traditional line to a mixed model production line. Due to the enlarged number of models, the design of an assembly system becomes more complicated. Performance evaluation is an important phase in the design of assembly lines in a mixed model production environment. Simulation models helped us to identify production line bottlenecks and evaluate some number of suggested solutions.

1 INTRODUCTION

The importance of a mixed model assembly line design increases in modern assembly systems. Traditionally, most assembly lines were a single model type, and as a result the design process was relatively simple.

Modern production systems compete in an extremely demanding market environment, where specific customer needs increase the number of models for each product (Miltenburg, 1989). As a result of the enlarged number of models, the design of an assembly system becomes more complicated (Hasgul and Özkul, 2002).

The main problems for the planner of mixed-model lines are the followings (McMullen and Frazier, 2000):

1. How to balance the line when different products have different work contents?
2. How to determine the optimum launch sequence which minimizes losses?

Compared to manufacturing large batches of end products, the mixed-model approach allows reducing inventories of both final items and subassemblies and components remarkably (Bard, et al., 1994)..

The use of JIT systems and mixed-model assembly lines has grown increasingly in recent years in order to satisfy the demand while minimizing inventory and diversifying small lot production (Monden, 1983).

The refrigerator company wants to adopt mixed model assembly lines to meet various demands without large finished goods inventories. However, depending on the new mixed model schedule of the final assembly line, the vacuum station may be unable to complete the vacuum process on a refrigerator. The performance of the production line is determined by its constraints. Therefore, in order to improve the performance, it is necessary to improve the constraints, also known as the bottlenecks.

The models have also been used for operations planning, training and the demonstration of AGV activities. Since the overall objective of the project is to validate of the mixed model assembly line design, the models included different types of refrigerator, an AGV, and flow lines.

The following steps were performed to achieve the overall goals of the project:

1. Developed an Arena simulation model to analyze the vacuum station and identify the AGV bottlenecks.
2. Conducted experiments with the model in order to understand and evaluate the system performance.
3. Identified the system bottlenecks and suggested solutions to eliminate bottlenecks and to increase the production line capacity.

The analysis also demonstrated that the AGV sequence and cell allocations are very important to improve the system performance.

2 PROBLEM DESCRIPTION

The work station we located around the production line and the conveyor system is used for the entity transfer between work stations. In work station, if one than one workbench exists, AGVs are used for the transfers. In the assembly line, if a bottleneck exists then it affects the entire process and performance of the production line. In the production line, vacuum station causes a bottleneck. To improve the throughput of the system, it is necessary to improve the bottlenecks.

In the vacuum station, there are 26 cells, 24 of them can used for the vacuum process, one cell for entry unit, and the other cell for exit. The vacuum processing time of the refrigerator body depends on product type. The bodies are carried to the systems by conveyors, to the vacuum stations by AGV and exit to the systems by conveyor. Before the body leaves the system there is a set-up process. An operator sets up the trunk; then the body exits the vacuum system.

The vacuum station layout is given in Figure 1. In Figure 1 the entrance part is denoted by "I"; an exit point is shown by using "O". The numbers in the cells are used to show vacuum stations. The last operating point is shown with "M" and "Line 1, Line 2, Line 3, and Line 4" are used for conveyors.

The cycle time of the system is 32 seconds. In other words, the time between the entry of a body to the system and the exit of another body from the system is 32 seconds. Cycle time of the system causes bottleneck, also while there are 9 bodies on Line 1, 10th body tries to use conveyor, the operations before the vacuum operations are delayed. This delay and bottlenecks affects the production line efficiency.

In Mixed Model Assembly lines, balancing the assembly line, deciding different products sequences and lot sizes are two of the main problems that have to be solved.

While trying to solve the problem there are some constraints;

1. Velocity of the AGV can not be increased. If the velocity increases, the body can fall down.
2. Vacuuming times are constants, and can not be changed.
3. Cost of the solution or suggestion must be low.

In the vacuum system the most significant factor is the AGV's performance. The vacuum times are constant and are difficult to decrease. AGV's performance is the key factor to prevent bottleneck, therefore any failure or insufficiency in AGV causes bottleneck.

There are two parts in AGV. One part takes the finished body from the cell; and the other part replaces the free cell with new trunk. Two parts move together at the same time. The AGV moves from one vacuum station to the next with FIFO rules. The numbered parts show the priority. Parts with small numbers have priority, AGV moves to entry. The AGV starts to replace the body in to the vacuums number 1 station.

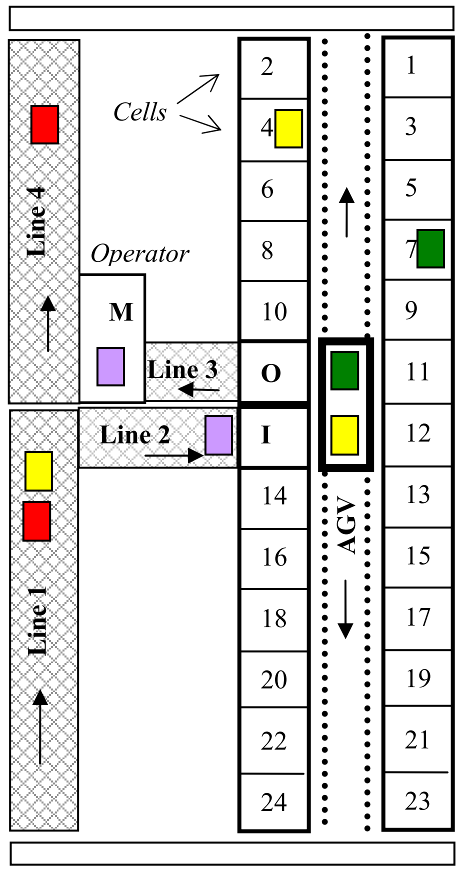


Figure 1: Vacuum Station Layout For New Mixed Model Assembly Line

The bodies are carried from Line 1 to Line 2. Line 1 carries bodies to Line 2. Line 2 carries it to the entry point. Capacity of Line 1 is 9 bodies, and Line 2 is 4 bodies. While 9 bodies are on Line 1, 10th body causes the bottleneck. When the bodies arrive to the entry point, a signal is sent to AGV to call it. Then AGV s movement starts.

After taking the body, AGV look for the vacuums station which vacuum operation has completed, if AGV cannot find any then it moves to the lowest-numbered idle vacuum station. If there is more than one station demanding the AGV, it selects the destination station according to FIFO rules. The AGV's cell selection logic is shown in Figure 2.

After the vacuum operations are completed, the bodies are carried in to set up operation points and their set up operation points queue capacity is one.

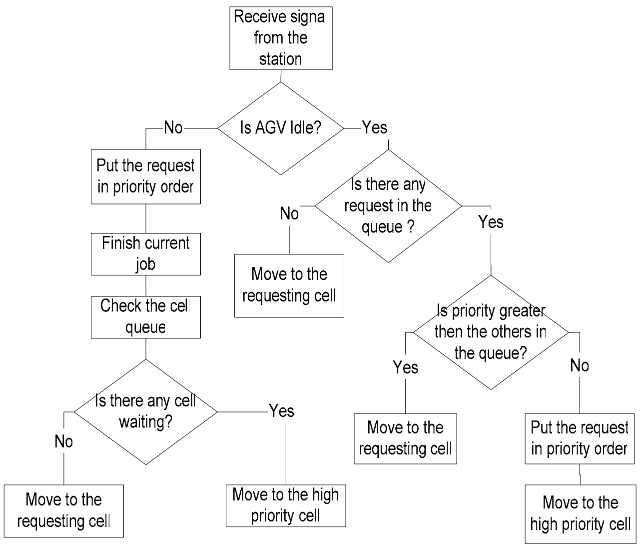


Figure 2: AGV's Cell Selection Logic

3 MODEL DEVELOPMENT

The purpose of the study is to solve the problem such that before using mixed model assembly line, how changes in the system can be made, how the cycle time of the vacuum systems decrease, decide the production sequence, and lot sizes, also shows the effects of suggested situations on the system performance, and compare the alternative with current situation.

The simulation model was developed using Arena. The Excel User Interface Module integrates into the simulation model with the data input. The User Interface Module creates the input parameters automatically to Arena and runs the simulation model. Upon reading the data and the model parameters, the simulation program executes and prepares the output file. Also, the simulation model has been developed to be flexible and useful.

3.1 Model Inputs

In mixed-model production systems, decision makers would ideally like to sequence the different products as evenly dispersed as possible, but without incurring an excessive number of set-ups due to switching between different products (assuming set-up times are non-negligible). A good sequence of products should not only have an acceptable level of product inter-mixing but also an acceptable number of required set-ups. In this environment, the sequencing decision is another problem.

An Excel-driven interface was developed for the production schedule input. The model assumes certain operational conditions and data. The important model assumptions and data are summarized below for the simulation model.

The following input data are needed:

- Production sequence and schedule
- Shift of the operators
- Time between arrivals
- Capacity of the conveyors
- Velocity of the conveyors
- Length of conveyors
- Queue Capacity
- Vacuum processing times
- Velocity of AGV
- Location of vacuum cells
- Loading and unloading times of the AGV
- Capacity of the AGV
- AGVs' acceleration and deceleration rates
- Failure frequencies
- Operator time out

The data related to capacities, velocities, acceleration and deceleration rates, length are obtained from the company. Loading, unloading times, time between arrivals, failure frequencies are observed and empirical distribution fittings were performed using Arena's built-in Input Analyzer. Assumptions in the model are as follows:

- There are three types of bodies that enter in to the system.
- Vacuum times are; 1st type: 10 minutes, 2nd type: 12 minutes, 3rd type: 15 minutes.
- The bodies arrive the system one by one.
- Every operator has 45 minutes for meal, and 15 minutes for tea break, twice in a shift. In this timeouts, bodies enter the system but no bodies exit the system.
- Unplanned breaks are 15% of the working time.
- During the vacuum process if failure happens, AGV does not work.
- Operator responds to the failure.
- In production line there are two shifts.
- Time between arrivals is change due to the body number in Line 1.

3.2 Simulation Model

Current situation of the vacuum system causes bottleneck, meaning that the capacity of the vacuum system is insufficient, but improving the number of vacuum station, the capacity of the AGV cannot response to the new situation. If the system works in full capacity, it is observed that a trunk, which has completed vacuum operation, waits 50 seconds for an AGV. In addition, current velocity of the AGV may cause unplanned waiting or delays.

Increasing of the vacuum stations such as from 24 to 44 seems to be possible, but AGVs become insufficient, and new AGV has to be purchased. Purchasing new AGV increases the cost.

For ease of presentation, we will refer to each vacuum station unit as a cell. In current vacuum system, small numbered cells have priority. In current situation; priority sequence are as follows (1, 2, 3, 4, ...,23 ,24). In our new suggested solution the priority sequence changes to 12, 11, 13, 14, 9, 10, 7, 8, 15, 16, 5, 6, 17, 18, 19, 20, 3, 4, 21, 22, 23, 24, 1, 2. In suggested priority sequence first cell is 12 which is the nearest station to the entry point (I). This sequence is nearest station to the farest station.

A detailed process layout was developed from which entities, location, resources, path networks for AGV, resources and processes were identified.

For analyzing the vacuum station simulation models were built using the Arena simulation software and sample Arena modules shown in Figure 3.

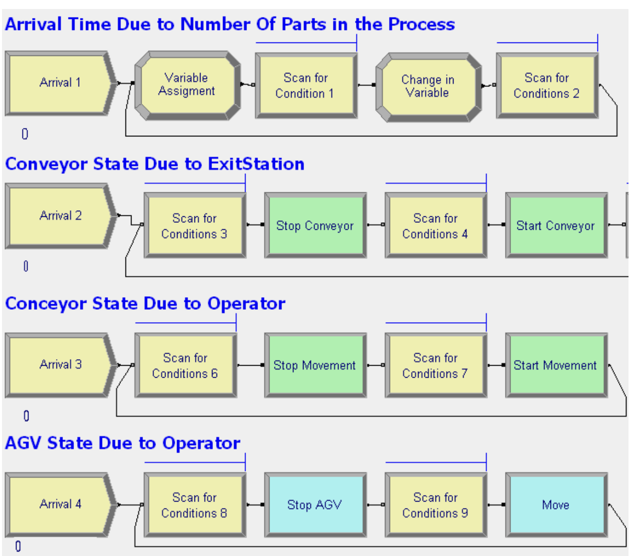


Figure 3: Sample Arena Modules For Vacuum Station Simulation Model

3.3 Validation And Verification

One of the most important steps of the simulation is validation and verification. If the model does not reflect the real system, outputs of the model has badly affect on the reliability and quality of the decision. The model was verified and validated to develop simulation model correctly reflects the production line behavior.

The simulation software Arena 6.0 is user-friendly for testing the model in visual way and every step it helps to the user to control the steps (Kelton, et al., 2004).

In non-terminating simulations, determining the warm-up period is important to analyze system behavior. To determine warm-up period it can be observed at what time the system reaches statistically stability. By using output analyzer warm-up period is determined. Figure 4 shows the output analyzer output to determine warm up period.

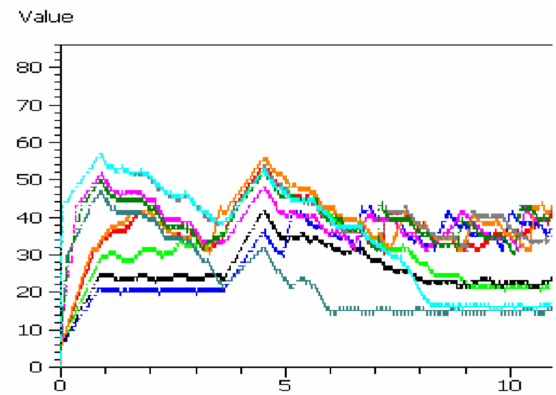


Figure 4: Determining Warm-Up Period

Run length determination was deemed essential since the simulation is a non-terminating simulation and running extremely long simulation is impractical.

4 RESULTS

To find the bottleneck experimentally, we conducted different simulation runs, and some performance measures are analyzed from the results. Figure 5 shows the comparisons of the two systems.

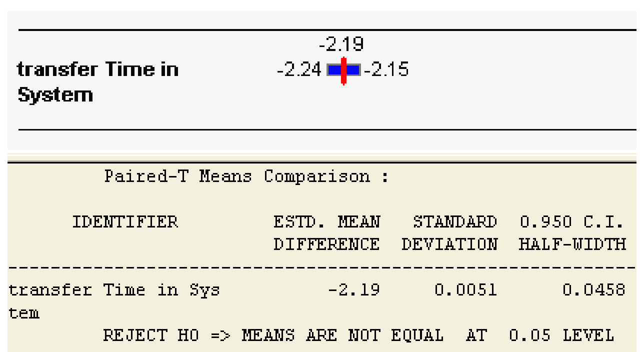
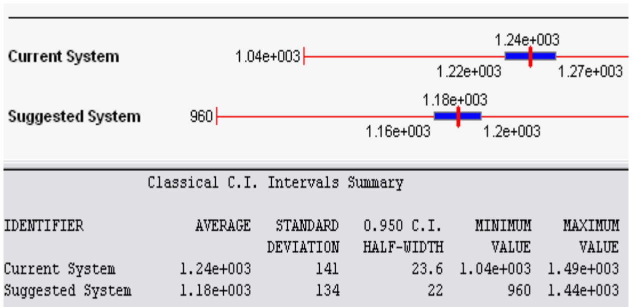


Figure 5: Comparing Two System

It seems from the 95% confidence intervals that changing the AGV's cell selection rule significantly improved the transfer time. We can say that improving transfer time of the AGV's is very important in maximizing the system performance.

By comparing the suggested system to the current system by using Arena 6.0 Output Analyzer in the 95% confidence level, suggested system has better performance than the current system can be seen in Figure 6. By changing the AGV's cell selection rule, cycle time of the system is reduced.



IDENTIFIER	AVERAGE	STANDARD DEVIATION	0.950 C.I. HALF-WIDTH	MINIMUM VALUE	MAXIMUM VALUE
Current System	1.24e+003	141	23.6	1.04e+003	1.49e+003
Suggested System	1.18e+003	134	22	960	1.44e+003

Figure 6: Comparison of Confidence Intervals

By means of developed simulation model, scenarios can be examined using model and used to prevent bottleneck point of the vacuum station by increasing number out, and decreasing cycle time, and waiting time of the vacuum station without interrupting the production line's production flow. Table 1 compare between two systems in some selected performance measures.

Table 1: Comparison of Two Systems in Selected Performance Measures

Performance Measures	Current System	Suggested System
Number out	27,838	28,767
Waiting time	382.77	334.16
Time in system (seconds)	1,243.06	1,078.43
Time between leaves	51.8751	50.0495

The results showed that the vacuum station is capable of serving the new mixed model production line system, by modifying the logic of the AGV's cell selection rule. The vacuum station has enough capacity for the different product mix. The analysis also demonstrated that the suggested AGV's cell selection rule more efficient than actual cell selection rule.

5 CONCLUSION

The purpose of this study is to develop a simulation model for a new mixed model production line. The production line was modeled using Arena to identify bottlenecks and evaluate vacuum station and an AGV performance, cycle times, and production data. This simulation model is developed for the rearrangement of the vacuum stations to prevent bottleneck of production line. The model takes the production schedule from Excel. With the help of Excel driven interface the model can be used to decide product mix and sequence, also to integrate the models with Excel means that this developed model can be easily integrated with other software. With this model, we aim to attract attention to bottleneck of production line.

The proposed approach might be applied to the same AGV systems in which mixed model production lines are adopted.

REFERENCES

Bard, J. F., A. Shtub, S. B. Joshi. 1994. Sequencing mixed-model assembly lines to level parts usage and minimize line length. *International Journal of Production Research*, 32, 2431–2454.

Hasgül, S., and A. E. Özkul. 2000. New Solution Approaches for the Multi-Criteria Mixed Model Assembly Line Balancing Problems. *Proceedings of the 21st National Meeting On OR/IE'2000*, Eastern Mediterranean University, 84-87.

Kelton, D. W., R. P. Sadowski, and D. T. Sturrock. 2004. *Simulation with Arena*, 3rd edition. Boston, Massachusetts: The McGraw-Hill Companies, Incorporated.

McMullen, P.R., and G. V. Frazier. 2000. A simulated annealing approach to mixed-model sequencing with multiple objectives on a JIT line. *IIE Transactions,* 32 (8), 679–686.

Miltenburg, J. 1989. Level schedules for mixed-model assembly lines in just-in-time production systems. *Management Science*, 35, 192-207.

Monden, Y. 1993. *Toyota Production System*, Second ed. The Institute of Industrial Engineers, Norcross, GA.

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