

USING SIMULATION AS A DECISION MAKING TOOL: PLANT EXPANSION CASE STUDY

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ABSTRACT

A leading manufacturer of air conditioning components is considering a plant expansion due to increasing sales forecasts. A new production line is to be added and it is not known whether the existing multi-line final test and packing area can handle the increased throughput. Simulation was used as a tool to estimate the capacity of the final pack area and determine how much capacity should be added, if any. The final pack area proved to be difficult to simulate due to complex, real-time routing decisions. Furthermore, the simulation model identified other areas for improvement and standardization. This paper provides an in-depth study of the project and lessons learned. Specific issues addressed include:

- modeling the final pack area using ProModel
- decision-making logic used to route the components
- verification of the simulation model
- results and conclusions of the simulation

INTRODUCTION

A classical use of manufacturing simulation is to analyze what-if scenarios without investing significant resources and capital. It allows one to determine the impact of changing key variables in a manufacturing process. Typical scenarios may include a different layout, increased or decreased variability in an operation, increase or decrease in the number of operators and/or machines, and implementation

of varying levels of automation. The impact of changing such variables includes creating or eliminating bottlenecks and improving or degrading operator/machine utilization, lead-time, and productivity.

For the application described in this paper, a manufacturer was interested in determining how much to expand a final test and pack area at the end of one production line to accommodate a second production line. In this particular plant, the main production line fed an overhead conveyor into the final test and pack area as shown in Figure 1. The parts are removed from the overhead conveyor, placed on a roller conveyor and sorted into one of two final test and pack lines. Each line consists of six stations labeled Station 1-6. Station 2 contains three duplicate machines on each line with the ones farthest from the arrival point receiving highest priority, second farthest receiving second priority, and so forth. The last station on each line is a sorting station where each part is matched with a particular order and assigned to the appropriate pack-out lane. However, if the part fails any of the tests, it is routed to the Reject station where the cause of failure is identified. It is then sent back to either Line 1 or Line 2 via the Reject Return Line. If the part passes all tests, it continues to the pack-out lanes. Currently, there are eleven pack-out lanes, two of which are used for parts that do not belong to an open order, or orphans. Parts accumulate in the pack-out lanes until they are either full, the order is filled or the lane is needed by another order. At that time, all parts are removed from the pack-out lane and placed on skids.

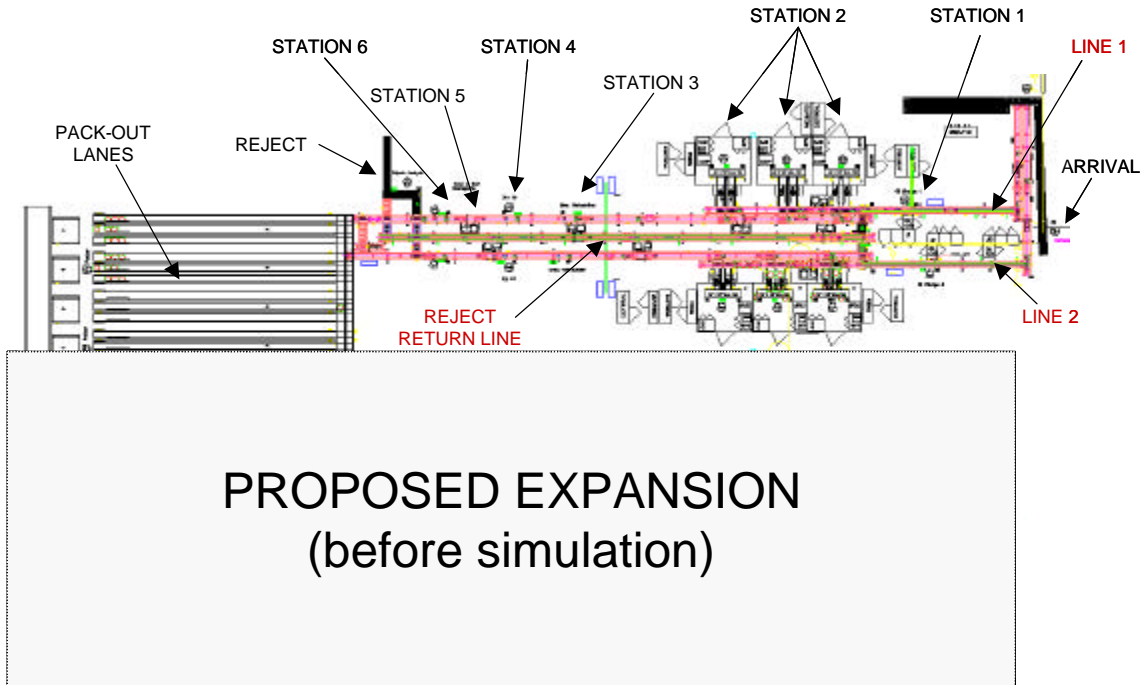


Figure 1. Final test and pack area

As shown in Figure 1, the proposed expansion, prior to the simulation activity, included two additional final test lines and seven additional pack-out lanes. Additionally, the extra final test lines required a building expansion. The objective of the simulation was to determine how many additional pack-out lanes and final test and pack lines were needed for a 50% increase in production. As will be shown, an entirely different pack-out area was devised and is in process of being developed.

SIMULATION MODEL

ProModel, a powerful manufacturing simulation software package by PROMODEL Corporation, was used to develop the model. Most of the model was straightforward with simple operations and conveyors. There were dedicated operators at each station and the arrival rate was virtually constant, since it was conveyor driven. The objective of the simulation was not to analyze bottlenecks or effects of variations in the operations, but to investigate capacity requirements over an extended period of time, so constant cycle times were used for all stations. Each part had

associated with it a model number that remained constant and each pack-out lane had an order number that varied as orders were filled. Each order number was linked to one model number and a quantity. There was only one model number per order. In order to verify the simulation model against actual performance, real-world data was used for the incoming part model numbers and orders. Model numbers were assigned to the parts upon arrival and orders for the run time were read in all at once into an array. When the part reached Station 6, it was matched to a particular order and assigned to the appropriate pack-out lane.

The difficulties in modeling the system involved the logic used to sort the parts and assign them to orders and pack-out lanes. The primary issue was the time lag between when a part was assigned to a particular pack-out lane at Station 6 and when the part actually arrived at the pack-out lane. Due to the filling of orders and occasional need to close a pack-out lane to accommodate a new order, the order assigned to a pack-out lane could change during that time. This would create a situation in which the part that was just assigned was being sent to a pack-

out lane that no longer matched the part's model number. To avoid this problem, all information was tracked at Station 6, including the status of each order number. The status for each order could be one of the following four at any given time:

- CLOSED COMPLETE – order has been filled and closed
- OPEN – currently active in a pack-out lane
- CLOSED INCOMPLETE – pack-out lane was forced to close before an order was filled to accommodate a new order (occurs when parts with the same model number get separated during production because of defects, random quality control checks, etc.)
- NOT YET OPEN – order has not been opened yet

Additional information in the array for each order included the model number and quantity remaining to fill it.

The steps performed at Station 6 for each part coming down the line are shown in Figure 2. After reading the model number, four passes were made through the orders array to determine if the model number matched an open order, an incomplete order, an unopened order or none of the above, respectively. Depending on the match, different actions were taken. Some required a pack-out lane to be closed short of filling an order, which required the lane that has been inactive the longest to be identified, the order currently assigned to it to be closed incomplete, and a new order opened (or reopened) and assigned to that lane. Also, the number assigned to each pack-out lane was tracked so a signal could be sent to pack it when it was full. The quantity of parts remaining to fill an order was also decremented. Parts not matching any order were sent to an orphan lane to be packed separately and stored until needed by a future order. These parts accumulated rapidly and were often not matched to later

orders, causing finished goods inventory to accumulate.

To complicate the problem even more, the Station 6 on each line (Line 1 and Line 2) only has access to certain pack-out lanes and they cannot share with each other. In other words, the Line 1 Station 6 can only access the first six pack-out lanes and Line 2 Station 6 can only access the last five pack-out lanes.

SIMULATION VERIFICATION

As previously mentioned, real-world data was used as input to the model, as opposed to statistically generated data. The purpose was to verify the model so any improvements would be credible. The metrics used to verify the model were the number and types of skids packed. The only data available were the number of skids with 32 parts, the number with 16 parts and the number with other amounts. It was also desired to measure the number of partial packs, or skids that are not full (32) because orders had to be closed incomplete. The actual partials data was not available for comparison, but the simulation model was setup up to collect it. The actual data is shown in Table 1 with the simulation results for two sets of data, one week each.

With the exception of the number of the 16-packs, the simulation results are similar to the actual data. Discrepancies could be caused by several factors, including:

- using constant instead of variable cycle times
- “hard” logic used at Station 6, where the operator has the ability to override decisions in reality
- slight variations in how rejected parts are handled and retested via the reject return line

For the purposes of this project and to analyze trends (not absolute statistics), the results are satisfactory.

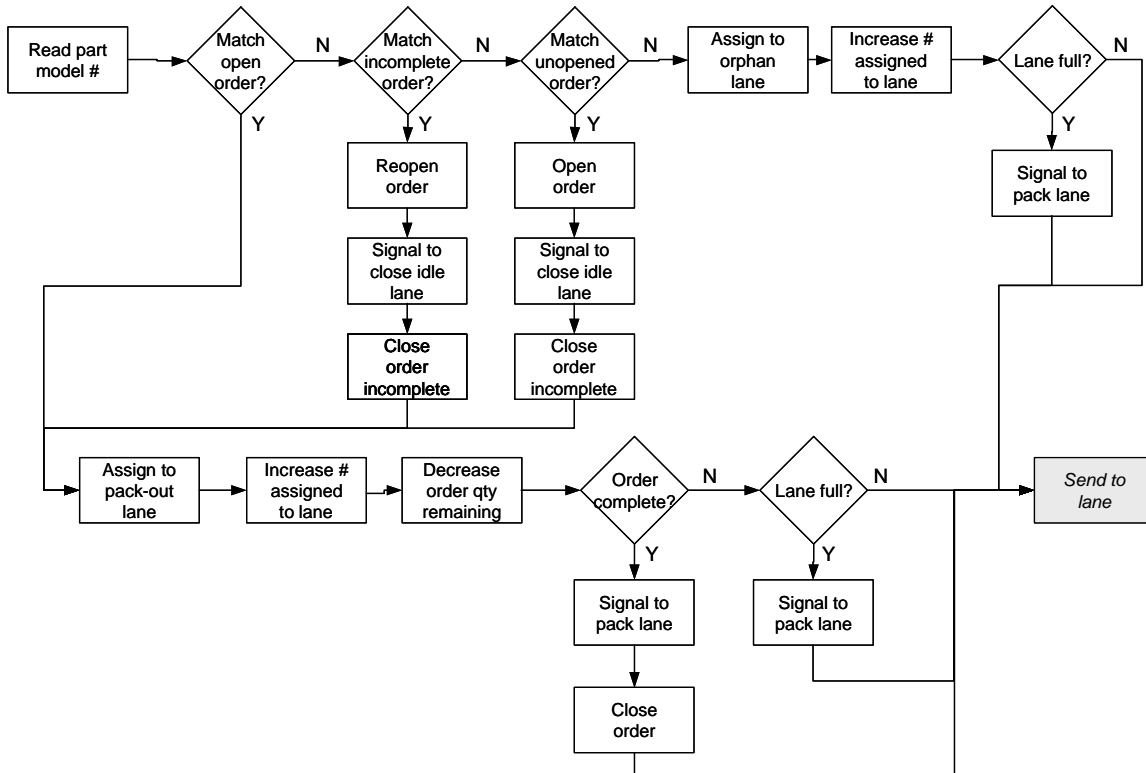


Figure 2. Logic at Station 6

Table 1. Actual data vs. simulation results

	Data Set 1				Data Set 2			
	Actual		Simulation		Actual		Simulation	
	Qty	%	Qty	%	Qty	%	Qty	%
32-packs	1009	81%	1030	76%	N/A	N/A	1070	68%
16-packs	38	3%	125	9%	N/A	N/A	254	16%
Other packs	206	16%	197	15%	N/A	N/A	280	18%
Total	1253	100%	1352	100%	N/A	N/A	1604	100%
Partial skids			210				264	

IMPROVEMENT SCENARIOS

Five alternative configurations were simulated to determine if improvement trends could be realized prior to adding additional lines and pack-out lanes. If so, it might be shown that the capacity of the current system could be increased without major modifications. The five configurations investigated are described below.

Configuration 1: Station 6 from Line 1 and Line 2 have access to nine of the eleven pack-out lanes. However, once a pack-out lane is

opened, only the Station 6 that opened it can use it until it is closed. The current restriction of not sharing lanes is lessened. Each Station 6 still has its own orphan lane.

Configuration 2: Same as Configuration 1, but only seven pack-out lanes are used with separate orphan lanes.

Configuration 3: Same as Configuration 2, but a skid is considered full with 16 parts instead of 32. This was an attempt to decrease the number of partial skids.

Configuration 4: Same as Configuration 1, but a skid is considered full with 16 parts instead of 32.

Configuration 5: Same as Configuration 1, but each Station 6 has complete access to all pack-out lanes. The restriction of not sharing is completely removed.

The results of the above configurations are summarized in Table 2 and Table 3 for two sets of input data. Not all configurations were run for the second data set. It should be noted that some configurations did not run to completion and data was linearly extrapolated to the total run time.

From the original configuration results shown in Table 1, the number of partials decreased from 210 for Configurations 1 and 5 and increased for the rest. For Configurations 1, 2 and 5, where the skids are considered full with 32 parts, the total number of skids remained somewhat constant. This was expected since the same input data was used for all configurations. It doubled for Configurations 3 and 4 because skids were considered full with 16 parts.

For the second data set, the number of partials increased from 264 for Configuration 1 and decreased for Configuration 5. This is

consistent with the first data set. It appears that total sharing of pack-out lanes is an improvement over the current configuration, although not dramatic. The monetary benefit is yet to be determined, as is the cost of implementing the necessary changes.

One final configuration is currently being investigated, but shows promising preliminary results. It involves removing all the pack-out lanes and placing parts on skids immediately following Station 6 without accumulating. Essentially, there would be a skid available for all open orders and the orders would not close until complete. A sketch of the layout is shown in Figure 3.

The benefits of this type of layout are:

- reduction in required floor space
- reduction in work-in-process
- elimination of need for assigning pack-out lanes
- possible reduction in lead time
- elimination of partial packs
- reduction in number of operators

There are also some disadvantages as follows:

- need for quick identification of matching order
- quick removal of the parts from the conveyor

Table 2. Results of improvement scenarios for data set 1

	Config. 1		Config. 2		Config. 3		Config. 4		Config. 5	
	Qty	%	Qty	%	Qty	%	Qty	%	Qty	%
32-packs	1030	76.5%	1025	74.5%	0	0.0%	0	0.0%	1143	76.4%
16-packs	125	9.3%	125	9.1%	2549	90.3%	2446	90.9%	133	8.9%
Other packs	191	14.2%	226	16.4%	274	9.7%	244	9.1%	221	14.8%
Total	1346	100.0%	1376	100.0%	2823	100.0%	2690	100.0%	1497	100.0%
Partial skids	197		237		258		246		195	

Table 3. Results of improvement scenarios for data set 2

	Config. 1		Config. 5	
	Qty	%	Qty	%
32-packs	1367	73.1%	1387	76.7%
16-packs	211	11.3%	136	7.5%
Other packs	291	15.6%	285	15.8%
Total	1869	100.0%	1808	100.0%
Partial skids	271		239	

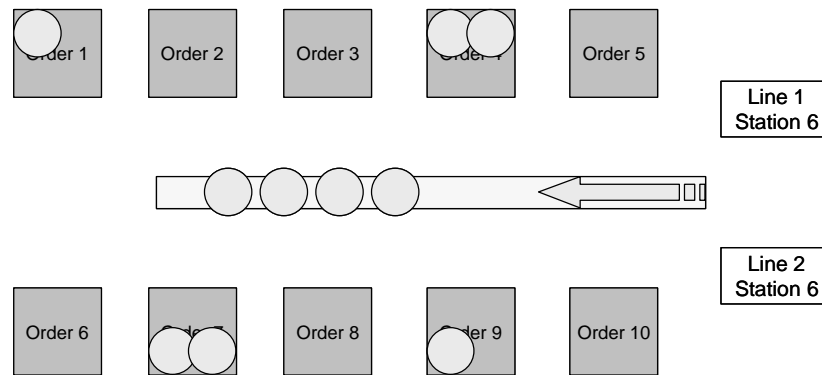


Figure 3. Direct pack layout

A preliminary simulation of this configuration shows that only a fraction of the floor space is needed in the pack-out lane area and it may be feasible to process the increase in productivity with fewer operations than originally thought and without expanding the building.

CONCLUSIONS

In summary, simulation is an effective method of providing insight into the impact of what-if scenarios in manufacturing applications. Through this case study, simulation allowed multiple configurations to be analyzed with multiple sets of real-world data. The results were used to identify improvement trends without the expense and/or loss of productivity via trial and error. It is also proving to be a method of significant cost avoidance by demonstrating that the initial expansion may not be necessary.

The following issues were identified as improvement opportunities with possible solutions demonstrated by the simulation models used in this project:

- The orphan assignments can be dramatically reduced, if not eliminated, thereby reducing the amount of finished goods inventory and the costs associated with it.
- Packing the parts as they leave Station 6 can eliminate the pack-out lanes. By doing so, the required floor space in that area can be reduced by approximately 50%.

Other areas identified by the simulation but not addressed include the waste of transporting the compressors back to the final test line on the reject return line and the under-utilization of some of the equipment at Station 2.

AREAS OF FURTHER DEVELOPMENT

Some areas requiring further development include:

- final development of the configuration outlined in Figure 3
- alternative solutions to a reject return lane
- improvement of logic to balance the load on the Station 2 machines and operators