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Modeling a Just-In-Time Plant Using Sequencing Algorithms

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Abstract

An Australian automotive component company plans to assemble and deliver seats to customer on just-in-time basis. The company management has decided to model operations of the seat plant to help them make decisions on capital investment and labour requirements. There are four different areas in seat assembly and delivery areas. Each area is modeled independently to optimise its operations. All four areas are then combined into one model called the plant model to model operations of seat plant from assembly to delivery. Discrete event simulation software is used to model the assembly operations of seat plant.

1 Introduction

Air International is an Australian technology provider designing, manufacturing and distributing interior parts such as seating, air conditioning, steering systems and heating systems for automotive, rail, heavy transport and bus applications. Air International has planned a new seat plant to assemble car seats for a car company. The new plant is designed to assemble different seats on an assembly line.

The objective of the research is to determine the bottleneck resources and balance work on seat assembly lines to assemble seats on a just in time basis.

The four different areas of seat assembly and delivery are:

a) Front seat assembly line
b) Rear seat assembly line
c) Finished goods inventory
d) Seat delivery to the customer

Figure 1 shows a block diagram of the four areas. The arrows indicate the direction of seat assembly and delivery. Discrete event simulation software Quest is used to model the operations of seat plant.

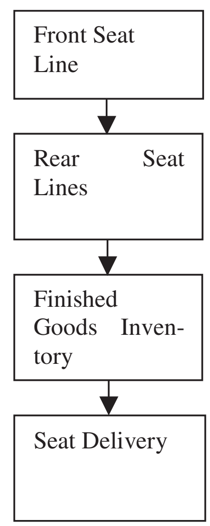

Figure 1 Seat Plant Model

1.1 Seat Types

There are 40 different seats to be assembled on the front seat assembly line. Seats can be classified into three different types based on their features.

1. Type 1 is a base seat
2. Type 2 is a medium seat
3. Type 3 is a luxury seat

More features require more time to assemble a seat.

1.2 Assembly Times

Assembly time of key workstations on front seat assembly lines are shown in Table 1 below

Models Assembly Time in Seconds			
Seat Type	Station 1	Station 2	Station 3
Type 1	45	57	60
Type 2	60	55	60
Type 3	60	55	50

Table 1: Seat Assembly Time Matrix

2 Front Seat Assembly Line

The front seat assembly line is described as a parallel and sequential assembly of front seats. The front seat cushion, front seat back and head rests are assembled on sub assembly lines connecting the main line at different points. Workstations on the subassembly line have small buffers, which can hold 4-6 seat parts. Seat assembly is done on a power and free conveyor-requiring operators at each workstation. Operators are the key resource in seat assembly process. The main assembly line is indexed after a cycle time determined by the customer to assemble seats on a just in time basis.

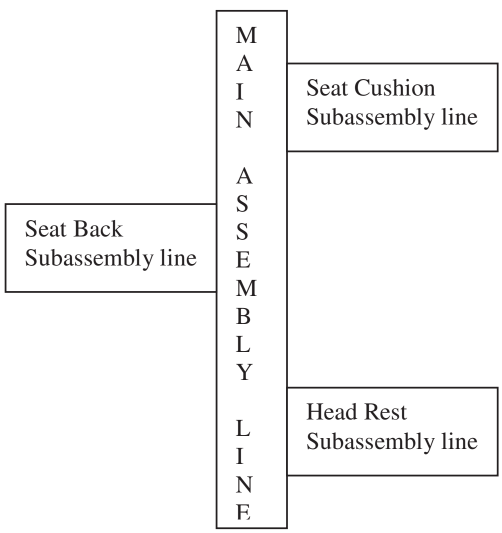

Figure 2: Front seat assembly block diagram

The front seat assembly line is designed based on industrial engineering data available from the sister companies. Initial estimates by the plant manager show 35 operators are assigned to the front seat line. Process times for different seats were recorded during the first build of seats for the customer. A process time matrix of seat types and assembly stations is formulated; part of which is shown in Table 1. Such a matrix is useful in designing a model with logical and

2.1 First model

Based on the data a front seat assembly model is built. The first model showed a number of bottleneck workstations in the front seat back area. Although the assembly times on each of the main line is balanced and showed no bottlenecks front seat back subassembly line showed two bottleneck workstations and front seat cushion showed one bottleneck.

The following information was derived from the first model

1. Three workstations were 100 percent busy during simulation runs whereas two operators were busy 22 percent of the time.
2. Other workstations were busy for an average of 45 percent of the shift time.
3. The first model line output was an average of 211 seats when compared to the expected seat output of 440 seats.
4. There is a limit to the number of different seat types that can be assembled on the front seat assembly line.

Figure 3 Front seat Model

Based on the observations in the first model operators were reassigned two under utilised operators were assigned to areas where the bottlenecks were observed and a second model was built.

2.2 Second model

The second model was built after reassigning additional operators to the bottleneck workstations. The second model showed significant improvements over the first model. Following observations were made:

1. Two workstations on front seat back line were 85% busy during simulation runs.

2. Other workstations were busy for an average 77% of the shift time.
3. The second model line output was an average of 400 seats i.e. 40 seats less than the required output.
4. There is a limit to the number of different seat types that can be assembled on the front seat assembly line. The limit a maximum of 35 percent Type 2 and Type 3 seats assembled in one shift operations.
5. The most important point in achieving higher seat output is sequencing different seat types also known as mixed-model sequencing.

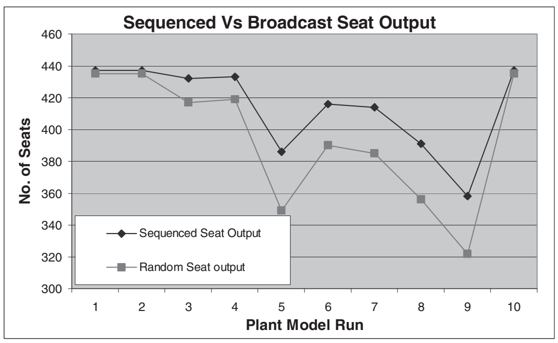

Figure 5 Sequenced seat output Vs broadcast output

2.3 Objective of mixed-model sequencing

Mixed-model sequencing can have various goals depending on the manufacturing environment. The objective of mixed model can be defined by first two points according to Monden [1]. They are

1. Leveling the load on each process within the line
2. Maintain a constant usage of parts along the assembly line.
3. Maximize throughput
4. Minimize assembly line length

Objectives vary depending on the type of product, customer requirement and other constraints.

2.4 Mixed-Model Algorithms

Industries and researchers have developed many mixed-model algorithms. Some of the commonly used and referenced algorithms are

2.4.1 Goal Chasing Algorithm I [1]
2.4.2 Goal Chasing Algorithm II [1]
2.4.3 Miltenburg Algorithm [2][3]
2.4.4 Time Spread Algorithm [4]
2.4.5 User Defined Algorithm

It was observed in the simulation that if seats were sequenced using goal chasing algorithm I or User defined algorithm higher output of seats was possible. The principle used is that Type 1 seats require less than a minute to assemble front seat backs but Type 2 and Type 3 seats require more than 1 minute to assemble front seat backs. If all types of seats are sequenced the main assembly line will not have to wait for front seat backs and hence lead to an increase in assembly of seats.

Using the sequencing algorithm and restricting the seat mix to 65 percent Type 1 and 35 percent Type 2 and Type 3 the seat output on the front seat line increased to an average of 440 seats in one shift.

3 Rear Seat Assembly Line

There are three rear seat assembly lines assembling various parts of the rear seat line. Rear seat assembly begins after front seats are completed and transferred to shipping pallets.

The first important factor that determines the number of rear seats that can be assembled on the lines is the number of utility vehicles assembled by the customer. The number can vary between 60 to 100. Utility vehicles have no rear seats; hence this allows extra time for rear seat assembly. Instead of a cycle time of one minute rear seats will have more than one minute to assemble seats depending on the number of utility vehicles assembled.

The second important factor is the conveyor between the front seat and rear seat line. The capacity of this section of the conveyor is 8 seat kits. If the conveyor is full it will block the front seat line and result in loss of production time.

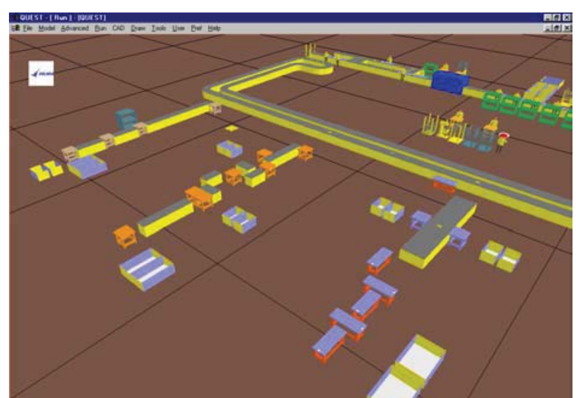

Figure 4 Rear seat Line Model

Objective of the rear seat lines is to

1. The number of utility vehicles required to be assembled.

2. To find if there are any bottlenecks in the rear seat lines
3. To find the number of seats on the conveyor between front seat line and rear seat line.

Rear seat line model showed following results
1. The minimum number of utility vehicles that need to be assembled is 60 numbers.
2. The time when the conveyor between front seat line and rear seat line is blocked resulted in an average blocking time of 3 minutes.
3. If more than 60 utility vehicles are assembled the average cycle time for rear seat line is 72 seconds. If less than 60 utility vehicles are assembled 2 extra operators are required on rear seat lines.

The rear seat line model did show a couple of bottlenecks but a Type 4 seat is added to the seat sequencing algorithm to ensure rear seat lines will have extra time to assemble seats as utility vehicles are spaced equally and give more time for rear seat lines.

4 Finished Goods Inventory (FGI)

The finished goods inventory can hold a maximum of 300 seat kits. The objective of the FGI is to act as a buffer between Air international and the customer. The customer sequence is used to pull seats out of the FGI and the same seat kit is assembled and replenished in the FGI.

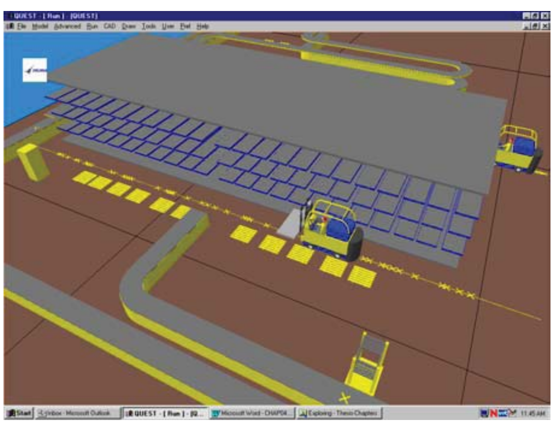

Figure 5 Finished Goods Inventory Model

There are two manual stock pickers used on either side of the FGI to load and unload seat in the FGI. There are 66 faces in the FGI at three different levels.

When the plant model was built the objective of this area was to find:
1. The number of stock pickers required
2. Average time required to load and unload seats from different locations in the FGI

This part of the model showed following results
1. The time required to load and unload seats from each location in the FGI is less than 1 minute. (Cycle time of front seat assembly line)
2. The average utilization of each stock picker was 57 percent and 55 percent respectively.

In conclusion FGI does not have any bottleneck resources and was crucial because of the 100 minute lead time available for delivery of seats to the customer.

5 Seat Delivery

Seat delivery involves delivering seats in sequence to the customer within a lead time of 100 minutes. A maximum of 24 seats can be delivered to the customer. There were two scenarios considered first when current model X is to be delivered. When the second model Y is to be delivered the capacity of the truck will vary on the mix of X and Y models.

The objective of this model is to
1. The number of trucks required
2. If Safety stock of 20 seats is maintained at the customer place.

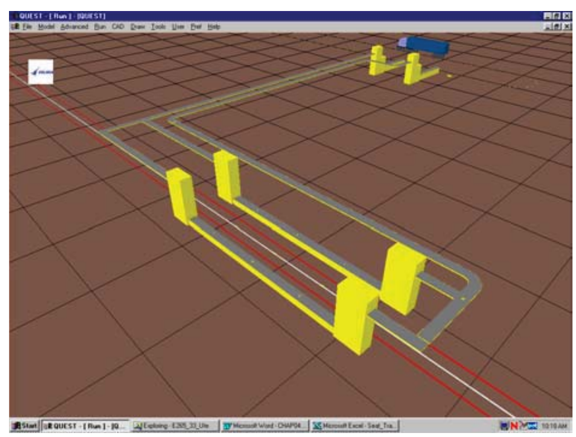

Figure 6 Seat delivery Model

This part of the model showed following results
1. Two trucks and one driver are required to seats to the customer.
2. A safety stock of minimum 20 seats is maintained during the entire shift.
3. When model Y is to be launched two trucks and two drivers will be required.

The seat delivery did not have any bottleneck resources but constitutes a significant amount of time in seat assembly and delivery when two trucks and one driver option is used.

6 Results And Discussion

In conclusion out of the four areas in the plant model the front seat line is the bottleneck area. Seat assembly begins at the front seat line and then rear seats are assembled. Using two algorithms to sequence seats increases seat output by distributing workload evenly among all the workstations on the front seat line. Keeping the option of using both algorithms would give more flexibility in sequencing seats on front seat assembly line as each algorithm has its advantage. It is possible in future each one may be used in different situations.

The actual time required to assemble a seat kit is 124 minutes and the available lead-time is 105 minutes. Hence it is not possible to assemble seat on a just-in-time basis and finished goods inventory is essential. The customer places an order on the FGI and the seat plant replenishes the seat kit in the FGI.

7 CONCLUSION

According to XYZ 70 percent of the time in manufacturing is Sequence generated by both the algorithms may not be optimum sequences but are good and are generated in short span of time.

A virtual model of the seat plant helped in 'what if ' analysis to determine the number of operators required in each area. The most critical part of the model was applying goal-chasing algorithm and user defined algorithm to sequence seats broadcast by the customer. It was decided to collect information on 30 or 60 seats broadcast by the customer sequence them using sequencing algorithm and achieve higher seat output which also resulted in better utilisation of operators across the seat plant.

References

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[2] J. Miltenburg, and S. Sinnamon, "Algorithms for Scheduling Multi Level Just-in-Time Production System", *IIE Transactions*, 24, 2: pp. 121 – 130, 1992.

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