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UNDERSTANDING MODULAR MANUFACTURING IN THE APPAREL INDUSTRY USING SIMULATION

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ABSTRACT

This paper summarizes the use of simulation in understanding the operational characteristics of modular manufacturing in the apparel industry. The modular manufacturing system that was evaluated was in operation at the Reece Corporation booth at the 1990 Bobbin Show in Atlanta.

1 INTRODUCTION

To respond to variation in style, quantities, and quick responses, apparel manufacturers are beginning to experiment with new manufacturing concepts. One of the most popular concepts is modular manufacturing. The American Apparel Manufacturers Association (AAMA) has defined modular manufacturing as:

> "a contained, manageable work unit of 5-17 people performing a measurable task. The operators are interchangeable among tasks within the group to the extent practical, and incentive compensation is based on the team's output of first quality product" (Gilbert 1989).

A number of apparel firms have implemented or are experimenting with modular manufacturing. A recent article in *Apparel Industry Magazine* (Kulers and Dewitt 1990) described the experiences of five companies with modular manufacturing: Lee Apparel Co., The Arrow Co., Jaymar-Ruby Group, Woolrich, and Jostens Graduation.The technical advisory committee of the AAMA has also evaluated a number of other companies that are experimenting with modular manufacturing including Russell Corporation, J.P. Hammill, OshKosh B'Gosh, and J.L. Miller & Sons (Horan 1988 and Horan 1989).

2 MODULAR MANUFACTURING

Figure 1 is a schematic of the layout of the Riverside Fashion manufacturing module that was in operation at the 1990 Bobbin Show in Atlanta, Ga. The module is U shaped with thirteen stations and five operators. Each of the operators is cross trained on several machines. The module makes ladies casual slacks, similar to sweat pants. The slacks are made in lots of one.

The operational characteristics of the module are given in Figure 2. Of special interest is the movement of the operators in the module. The making of a garment follows a counter clockwise movement. Operators are standing and also move counter clockwise with the garment. An operator will continue moving counter clockwise with the garment to the next station and perform the operation until the operator reaches an operator. The garment is then passed to the operator. The operator will return in a clockwise direction until there is an available garment. If there is no waiting garment, the operator will interrupt the first reached operator. The interrupted operator will then move clockwise to either find an available garment or another busy operator to interrupt. The interrupting operator will then complete the interrupted operation.

3 SIMULATION MODEL

The WITNESS simulation system Version 5.0 (Istel 1986) was used to develop the simulation model of the

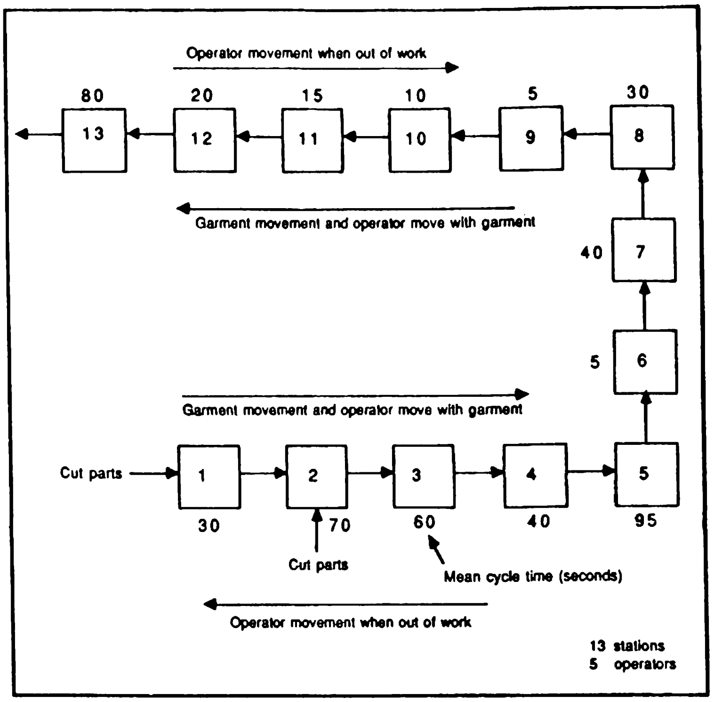

Figure 1: Modular Manufacturing Sytem Layout

- Module layout is U shaped with 13 stations and 5 operators.
- Module makes ladies causal slacks.
- Module makes garments in lots of 1.
- Operators are crossed trained on some of the machines.
- Garments move counter clockwise in the module. Operators move counter clockwise with the garment and also move clockwise for more additional work.
- An operator performs an operation at a station and will move counter clockwise with the garment to the next station and perform the operation. The operator will continue moving counter clockwise to the next station and perform the operation until the operator reaches an operator at a station. The garment is then placed in front of the station, or passed directly to the operator, if the operator is free.
- Operator 1 performs differently. Operator 1 will sew two pockets at Station 1 and will then move to Station 2 and perform the operation unless there is a free operator at Station 2. If there is a free operator at Station 2, Operator 1 will return to Station 1. Operator 1 will not proceed beyond Station 3.
- Station 5 also performs differently because of the long cycle time. If WIP exists at the buffer before Station 5, the operator will continue to perform Operation 5. If there is no WIP at the buffer before Station 5, then the operator will move with the garment to Station 6, assuming Station 6 is free, and will perform according to the previously defined constraints.
- If an operator is not busy, the operator will move clockwise until there is an available garment. If there is no waiting garment, the operator will interrupt the first operator she reaches. The interrupted operator will then move clockwise to either find an available garment or another busy operator to interrupt. The interrupting operator will then complete the interrupted operation.
- Operator 2 will never interrupt Operator 1 at Station 1.

Figure 2: Operational Characteristics

Modular Manufacturing System. WITNESS is a visual, interactive simulation system designed specifically for manufacturing domains. WITNESS has been designed so the modeler does not have to program in a language. Instead, the modeling process is object oriented and consists of the following phases: define, display, and detail.

The WITNESS model has a number of unique features that were implemented to realistically model the operational characteristics of the modular manufacturing system. The most complex modeling feature was the movement of the operators inside the model, since the operators could move either counter clockwise or clockwise. A number of IF-THEN-ELSE rules were defined to control the operator movement.

The following assumptions and constraints are used in constructing the WITNESS simulation model:

- All operators perform at the same efficiency at each station.
- Cycle time at each station follows the normal distribution with a standard deviation of 15 percent of the mean time. The large standard deviation includes the added time for garment rework.
- Machines have no down time.
- Time for the operators to move between stations is assumed to be zero since the sewing tables are next to each other.
- There are always cut parts waiting at Station 1 and Station 2. Therefore, the system never has to wait on incoming parts.

4 OUTPUT ANALYSIS

Generally there is no single point in the simulation beyond which the system is in equilibrium. Therefore, the problem is to find the point beyond which the modeler is willing to neglect the error that is made by considering the system in equilibrium. One common approach in determining equilibrium is to execute the model for such a long period of time that the system performance would not depend on the starting condition of the model. However, in most situations, the error because of the initial condition, or initial bias, must be taken into consideration.

The approach used to model the starting condition is to start the WITNESS model with all the queues or buffers empty, and all the facilities or machines idle. The approach used to model the stopping conditions is to stop the simulation after a given time period, thus leaving machines busy and parts in buffers.

A number of heuristic approaches are studied by Gafarian, et al (1978) to determine system equilibrium. The deletion method was used in this model and consists of plotting the cumulative mean without deletions, with the first value deleted, the second value deleted, and so on (Banks and Carson 1984). From these plots one can subjectively determine the truncation point by observing whether the curve approaches a straight line.

The modular manufacturing model was run for 80 hours and statistics collected after each hour. The selected response variable was hourly production. A number of curves were plotted from zero to 4, 8, 12, 16, and 28 deleted points. The plots indicate that the truncation point was the sixteenth hour. Plots for 0, 8, 12, and 16 deleted points are given in Figure 3. It was assumed that the first 16 hours are needed for the system to reach equilibrium.

The batching method was used to determine the confidence interval for the response variable, hourly production. If the batch size is correctly selected, the batch means can be assumed to be independent of each other and approximate the normal distribution. For the modular manufacturing system, the simulation run length was initially set for 80 hours with the first 16 hours needed for the system to reach steady state. Therefore, there are 64 hours remaining for the output analysis. The results of using the batch method indicated that the standard deviation tends to decrease as batch size increases, as expected. The smaller batch sizes showed a significant correlation between batches. The larger batch sizes of five or more showed no significant correlation. The selected batch size of 6 resulted in a half width of 0.149.

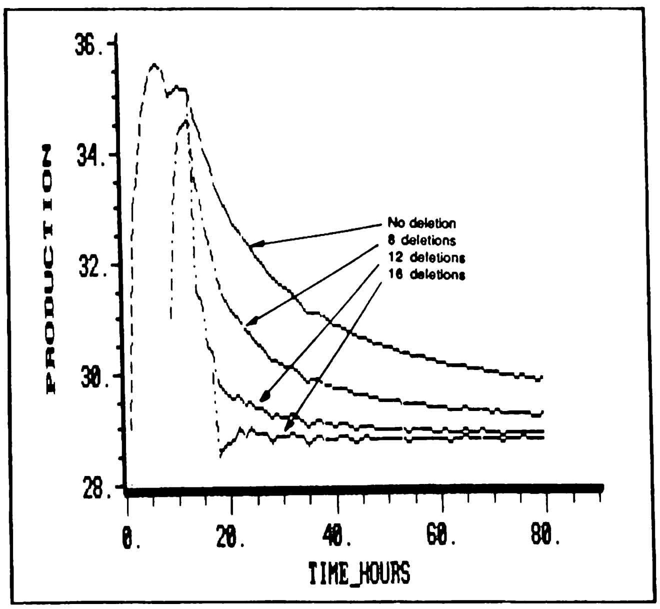

Figure 3: Cumulative Average Production Versus Time

5 EXPERIMENTATION

5.1 Baseline Run

The baseline run consisted of executing the model as previously defined. A production of 220 garments was achieved in a six hour shift. The stated production goal at the Bobbin Show was 206 garments in six hours. Therefore, the model's production closely approximates the actual production.

The simulation results indicated that the average WIP in the module was 13 garments. The WIP in the module at the end of the simulation was eight garments. By definition, two garments were always at BUFFER B(1). Therefore, the average WIP was 11 garments, with six garments in the module at the end of the simulation.

The utilization of the 13 stations was low as anticipated. For example, Stations 6 and 9 were each utilized 5 percent. On the other hand, Station 5 was utilized 100 percent and Station 13 utilized 80 percent.

The utilization of the five operators is given in Table I. Each operator was utilized 100 percent during the simulation. Operator 1 worked at four stations, Operator 2 at four stations, Operator 3 at five stations, Operator 4 at eight stations and Operator 5 at six stations. Operator 1 spent 91 percent of the time at Station 1 and 2, Operator 2 spent 88 percent at Stations 3 and 4, Operator 3 spent 92 percent at Station 5, Operator 4 spent 63 percent at Stations 7 and 8, and Operator 5 spent 92 percent at Stations 12 and 13. The operations at stations 6, 9, 10, and 11 have very small cycle time and therefore required only a small amount of operator time.

Table I: Operator Utilization for Baseline Run

	Operator				
Station	1	2	3	4	5
1	29	-	-	-	-
2	62	5	-	-	-
3	7	51	-	-	-
4	2	37	2	-	-
5	-	7	92	1	-
6	-	-	2	3	-
7	-	-	6	35	-
8	-	-	2	28	1
9	-	-	-	4	1
10	-	-	-	8	2
11	-	-	-	11	5
12	-	-	-	9	12
13	-	-	-	-	80
Idle	-	-	-	-	-
Total	100	100	100	100	100

Notes
1. - Indicates operator never worked at station
2. % utilization does not add to 100% because of rounding error

5.2 Variation in Number of Operators: Alternative A

Figure 4 is a plot of the production versus number of operators. Figure 5 is a plot of the production per operator versus number of operators. The baseline run with five operators indicated a production of 220 garments in a six hour day and a production rate of 44 garments per operator. With four operators in the module, the production reduced to 173 garments. With three operators in the module, the production reduced to 131 garments. Adding additional operators did not increase production. On the other hand, the production per operator remained relatively constant between 43 and 44 garments per operator.

Production did not increase by adding more operators above five. Therefore, the production per operator decreased as more operators were added to the module. This is anticipated since the theoretical production limit with the given cycle time is 216 in six hours.

The average WIP as a function of operators is given in Figure 6. Average WIP dropped from 11 with five operators to 7 with four operators and to 3 with three operators. On the other hand, WIP increased to 310 with six operators, to 350 with seven operators, and to 344 with eight operators.

5.3 Reduction in Station 5 Cycle Time: Alternative B

Since all the operators in the baseline run are being utilized 100 percent, another possible method to increase production is to reduce the cycle time at the station with the largest cycle time which is Station 5. Figure 7 is a plot of production versus cycle time at Station 5 with five and eight operators. No increase in production was achieved by decreasing the cycle at Station 5 with five operators. However, an increase in production was achieved by both reducing Station 5 cycle time to 85 seconds and increasing the number of operators to eight.

6 CONCLUSIONS

The following conclusions are made concerning the modular manufacturing system from the baseline run:

- Production of 220 garments per shift closely approximated the production goal of 206 garments.
- Each operator worked predominantly on just one or two machines.
- Operator 4 required the most training and worked on eight stations.

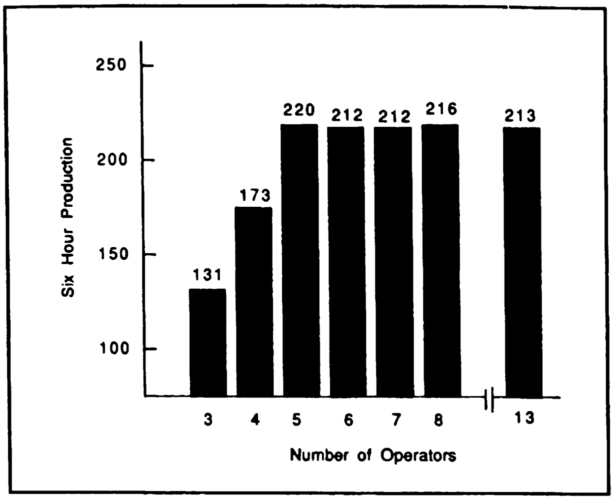

Figure 4: Production Versus Number of Operators

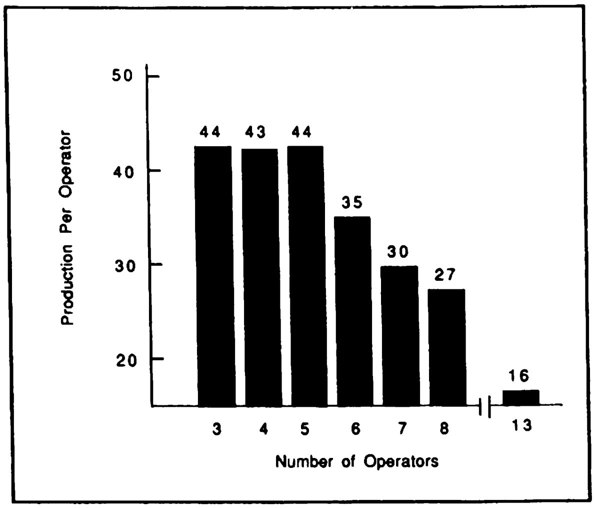

Figure 5: Production per Operator Versus Number of Operators

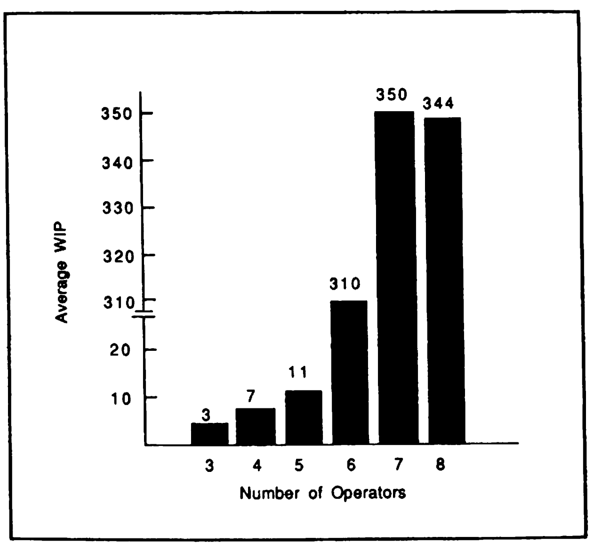

Figure 6: Average Work-in-Progress

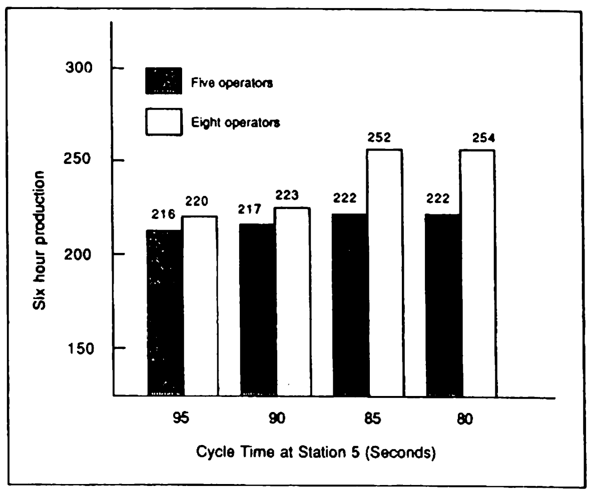

Figure 7: Production Versus Cycle Time at Station 5

- Station utilization was low and varied considerably based on the cycle time. This low utilization is anticipated because of the 13 stations and only five operators.
- Operator utilization was 100 percent.

The following conclusions are made based on Alternatives A and B:

- Production dropped by reducing the number of operators. Production did not increase by increasing the number of operators above five. This is anticipated since the analytical limit is 216 garments.
- Average WIP dropped from 10 with five operators to 7 and 3 with four and three operators, respectively. WIP increased to over 300 with six or more operators.
- Production remained constant with five operators by lowering the cycle time at Station 5 from 95 seconds to 80 seconds. However, production increased to 252 by lowering the cycle time at Station 5 to 85 seconds and at the same time increasing the number of operators to eight.
- Average WIP remained over 300 by decreasing the cycle time at Station 5 from 95 to 80 seconds.

In summary, the following general observations are made of the modular manufacturing system:

- System is well balanced with 13 stations and five operators even though there is a wide variation in station cycle times. This balancing is achieved by the ability of the operators to move within the module. Production will decrease with less than five operators and will not increase with more than five operators.
- WIP at each station is minimal and generally averaged one garment.
- Five operators do not need to be cross trained on all stations. Instead, each operator worked in a zone of only a few machines.
- Operator utilization was 100 percent while station utilization varied widely as a function of station cycle time. The apparel stations are rather inexpensive averaging $2,500 and therefore an idle station is not critical.
- Module can still produce garments even though an employee is absent. Therefore, management can readily control modular production based on customer demand and orders.

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