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A GENERIC SIMULATOR FOR MODELING MANUFACTURING MODULES

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ABSTRACT

This paper presents a simulator for designing and analyzing modular manufacturing lines. Included in this paper are a description of the simulator, a sample application, and the benefits of using this approach.

1 INTRODUCTION

Computer simulation has become a common and accepted tool in the design, layout, and analysis of manufacturing lines. Many companies will not install a new manufacturing line until the line has been evaluated using simulation. Management now sees simulation as inexpensive insurance against costly mistakes.

However there are still some pitfalls in using simulation. Probably the most serious pitfall is the time to build, verify and validate a simulation model. Model development takes time and generally more time than estimated and than often available. In addition, detailed data for the simulation model is often nonexistent, unreliable, and generally difficult to obtain.

Another pitfall in simulation is the need for an employee who knows how to build a simulation model, is experienced in using a simulation package, and has a general background in simulation and statistics. Quite often firms lack this expertise and cannot afford a full time simulation modeler.

One approach to reducing the pitfalls is the use of simulators. The advantages of simulators are relative ease of use, rapid model development, and changing model parameters.

2 BACKGROUND

In 1989 the University of Alabama in Huntsville (UAH) was awarded a contract by the State of Alabama to provide technical assistance to the apparel industry. As part of this contract, visits were made to over one-hundred apparel manufacturers in Alabama. A common response from these manufacturers was the need for assistance in converting their traditional manufacturing lines to modules (Gilbert, 1988; Kulers and Dewitt, 1990; Fralix, et.al., 1990; AAMA, 1987; Holoyda, 1992; Kron, 1987). As a result, a number of simulation models were written for designing and analyzing the proposed manufacturing modules (Schroer, 1990; Schroer, et.al., 1992, and Farrington, et.al., 1994).

Surprisingly, after developing these models, it was noticed that:

- Management wanted a quick design and analysis which resulted in the development of high-level models.
- The manufacturing modules were very similar for all the manufacturers.
- The manufacturing modules were generally U-shaped and did not have branches, such as diverging and converging lines.
- The simulation models were also similar and used identical features of the simulation package.

As a result of these observations, a generic modular manufacturing simulator (SSE5) was developed with partial funding from the NASA Marshall Space Flight

Center (MSFC), Schroer and Wang (1992). The inputs to the SSE5 simulator are:

- Number of stations and operators.
- Number of machines at each station.
- Cycle time for each station.
- Operator assignment (fixed at a station or moveable and if movable, the station routing sequence).

The SSE5 outputs are production, queue statistics, machine utilization, and operator utilization. The simulator is distributed through the NASA Marshall Space Flight Center technology transfer program. Since 1993, over 800 firms have requested copies of the simulator.

3 MODULAR MANUFACTURING SIMULATOR

Although the SSE5 was developed specifically for the apparel manufacturing industry, the feedback from a number of users indicated that it could be used in other domains such as electronics or small electromechanical assembly. As a result, the SSE5 simulator was modified to a generic Modular Manufacturing Simulator (MMS).

3.1 System Description

An overview of the Modular Manufacturing Simulator is given in Figure 1. The MMS can be used for designing and evaluating modular manufacturing lines with the following characteristics:

- The system consists of one line with an unlimited number of stations (all stations are in series).
- Each station may have unlimited number of machines with each machine performing the identical operation.
- There are an unlimited number of operators.
- There is unlimited space for work-in-process (WIP) in front of each station.
- There is always enough WIP in front of the first station so there is no delay waiting for parts.
- Some operators may be fixed at specific stations.
- Some operators may move between a given number of stations. The movement of operators is defined by a set of predefined rules.
- Work is done in lots of one part. However, it is possible to perform work in lots of more than one part by defining all parameters in terms of lots.
- There is no machine breakdown.

The MMS runs on a PC, with a minimu of 8Mb of memory, under the Windows operating system.

3.2 Operator Movement Rules

Each non-fixed operator moves based on one of the following rules: Maximum WIP Rule, Rabbit Chase Rule, and Push/Pull Rule. Figure 2 illustrates each of these rules for operator movement between three stations.

The WIP Rule is as follows:

- If the operator has worked for more than the time limit or has exceeded the part limit at the current station, or the WIP at the next station has exceeded the WIP limit, the operator will move to the station on the priority list with the largest WIP.

- If the maximum WIP is at the current station, the operator will stay at the current station and complete another part.

- If the station with the maximum WIP is busy, the operator will move to the station on the priority list with the second largest WIP.

- If two stations have the same WIP, the operator will move to the station with the higher priority.

- If all stations are busy, or there is no WIP at any station in the priority list, the operator will stay at the current station and make another part.

The Rabbit Chase Rule is as follows:

- If the operator has worked for more than the time limit or has exceeded the part limit at the current station, or the WIP at the next station has exceeded the WIP limit, the operator will move to the next station in the priority list.

- If the next station is busy or there is no WIP at the station, the operator will skip the station and go to the next station on the priority list.

- If the operator is at the last station on the priority list, the operator will try to move to the first station on the priority list.

- If all stations are busy or there is no WIP at any station, the operator will stay at the current station and make another part.

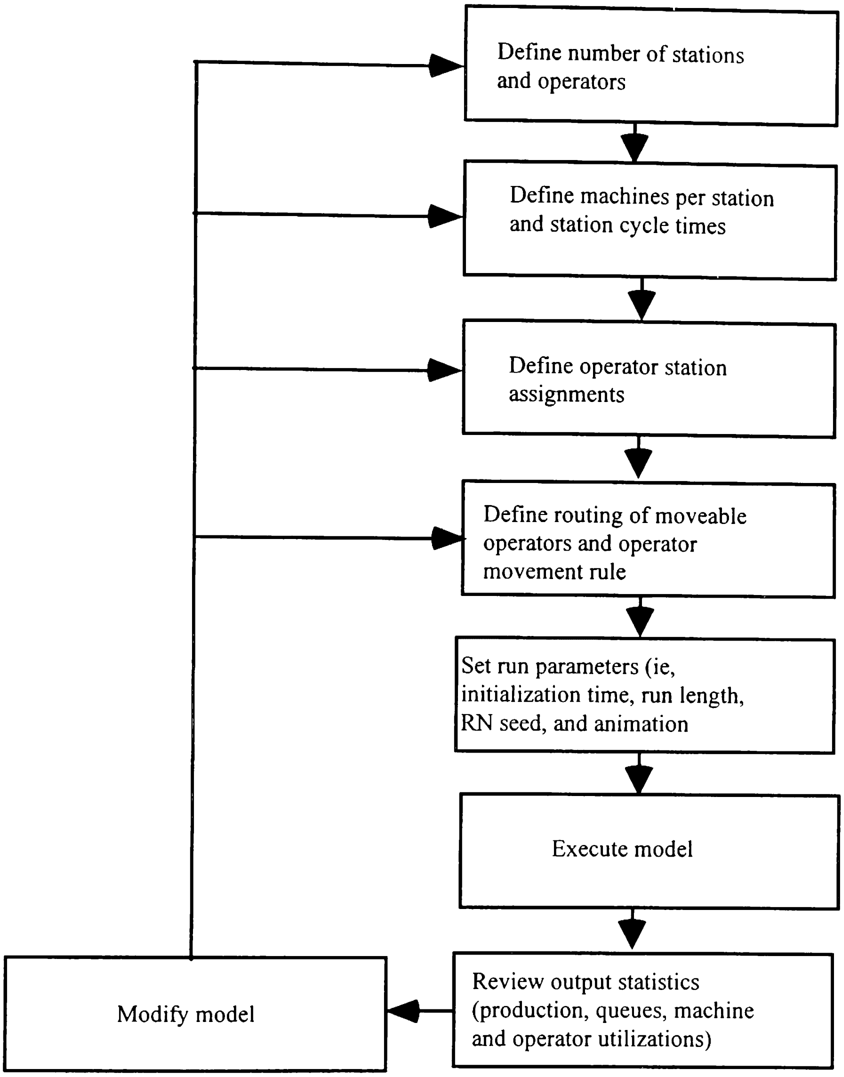


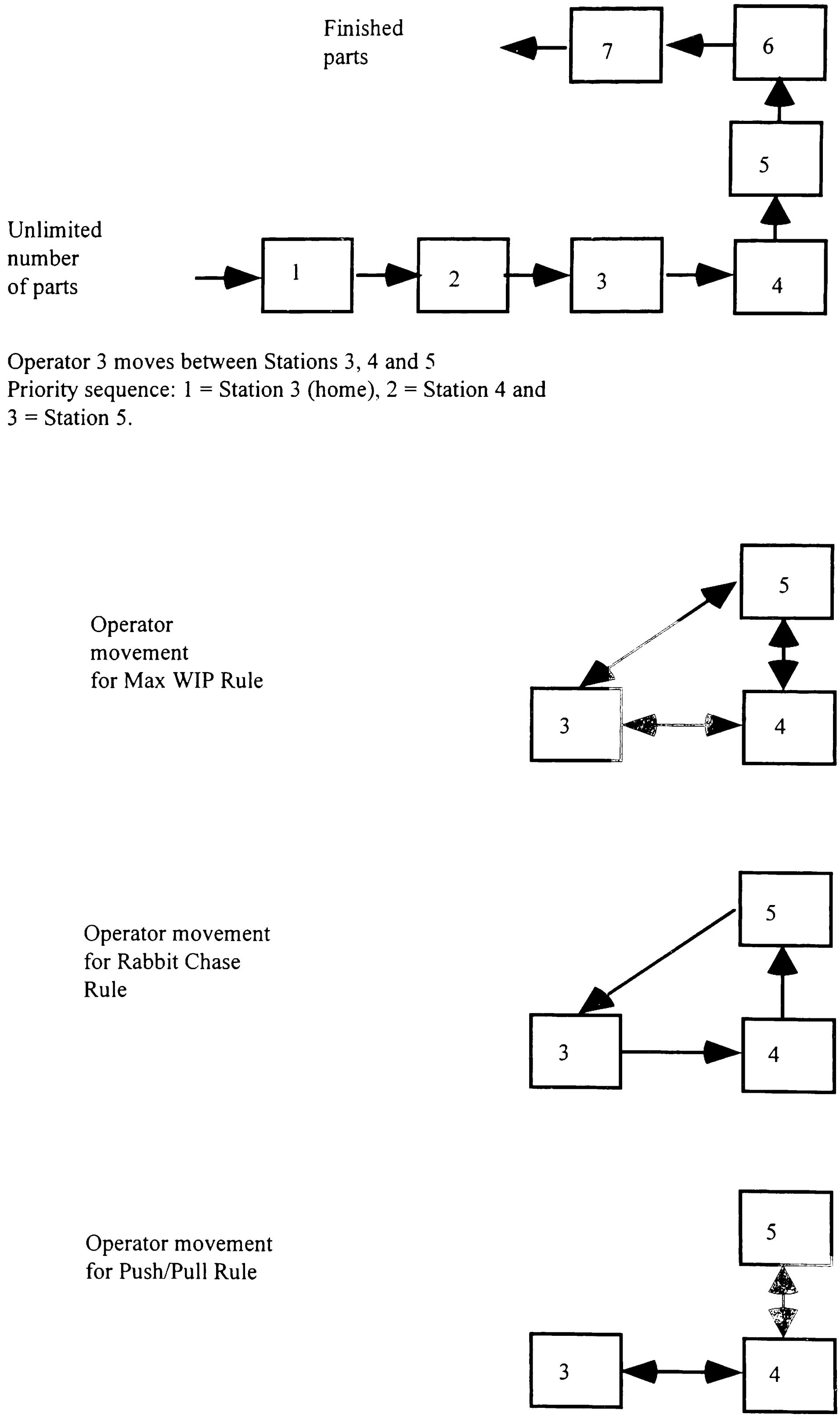
Figure 1: MMS system overview

The Push/Pull Rule is as follows:

- If the operator has worked for more than the time limit or has exceeded the part limit at the current station, or the WIP at the next station has exceeded the WIP limit, the operator will move to the next station on the priority list.
- If the next station on the priority list is busy or has no WIP at the station, the operator will skip the station and go to the next station on the priority list.
- If the operator is at the last station on the priority list, the operator will move back one station on the priority list. If this station is busy or has no WIP, the operator will move back two station on the priority list.

4 SAMPLE PROBLEM

Figure 3 is an example of a typical manufacturing line that can be evaluated using the Modular Manufacturing Simulator. Tables 1, 2, and 3 describe the inputs to the MMS. These tables are input through three MMS spreadsheets. The MMS outputs are typical simulation outputs and include:



Operator 3 moves between Stations 3, 4 and 5
Priority sequence: 1 = Station 3 (home), 2 = Station 4 and
3 = Station 5.

Operator movement for Max WIP Rule

Operator movement for Rabbit Chase Rule

Operator movement for Push/Pull Rule

Figure 2: Example of operator movement rules

- Production
- Queues - number in and out, average content, average time in queue, minimum and maximum content, and current content
- Machine utilization - WIP, percent busy, and number of operations
- Operator utilization - percent at each station and percent idle

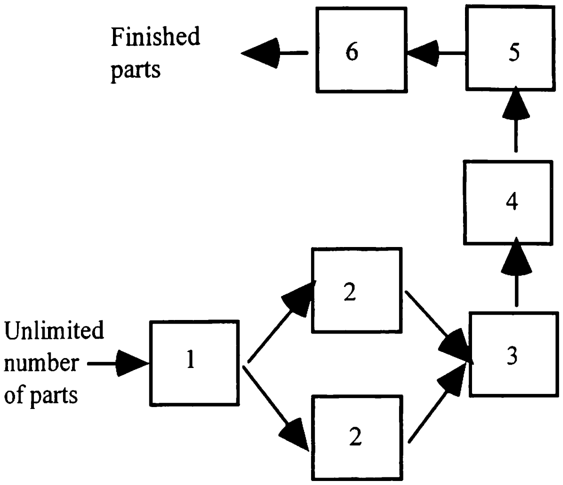


Figure 3: Typical manufacturing module

Table 1: Cycle time input

Station	Number of machines	Cycle time (minutes)
1	1	L(30,3)
2	2	L(60,12)
3	1	L(10,3)
4	1	L(12,2)
5	1	L(8,3)
6	1	L(10,3)
7	1	L(28,5)

L(x,y) = log normal distribution with mean x and standard deviation y

Table 2: Operator assignment input

Operator	Type	Station Assignment	Operator Efficiency (%)
1	Fixed	1	100
2	Fixed	2	100
3	Fixed	2	100
4	Moveable	3(home),4,5	3=100, 4=90, 5=90
5	Fixed	6	100

Table 3: Moveable Operator 4 input

Station	Priority	Time limit	Part limit	WIP limit	Movement Rule
3	1(home)	30	100	50	Rabbit Chase
4	2	30	100	50	Rabbit Chase
5	3	30	100	50	Rabbit Chase

5 CONCLUSIONS

In summary, the following observations can be made about the Modular Manufacturing Simulator:

o The MMS has been successfully used to develop models for apparel, electronics, and electromechanical manufacturing domains.

o A model of a manufacturing module could be developed and executed in less than fifteen minutes.

o Most firms had the necessary data available to construct the MMS model. For example, most firms had a data base of standard times. A good assumption is to use a log normal distribution for the standard times with the standard deviation expressed as a percentage of the mean. A simple sentivity analysi on the standard deviation can be done.

o The lack of animation was not really a drawback since the manufacturing modules are relative straightforward and easy to visualize.

The Modular Manufacturing Simulator has become an invaluable tool for supporting the State's Manufacturing Extension Program (MEP) which is funded in part by the National Institutes of Standards and Technology (NIST). The MMS offers the State MEP the ability to demonstrate the power of simulation to small and medium manufacturers and to actually model a client's manufacturing module quickly and at their manufacturer's location.

A followup evaluation by the NASA Marshall Space Flight Center has indicated that the SSE5 has been one of the major contributors to the economic impact of the MSFC technology transfer program (Tyson, 1996). One apparel manufacturer responded that the use of the simulator has resulted in an annual savings of $2M. These results indicated that the simulator is being used and having an impact on improving a manufacturer's productivity and competitiveness.

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REFERENCES

AAMA, 1987: *Getting Started in Quick Response*, American Apparel Manufacturers Association Arlington, VA.

Farrington, P.A., B.J. Schroer, J.J. Swain and Y.C. Feng, 1994, "Simulators as a Tool for Rapid Manufacturing Simulation," *Proceedings of the 1994 Winter Simulation* Conference, eds. J.D. Tew, S. Manivannan, D.A. Sadowski, and A.F. Seila, December 11-14, Orlando, Florida, pp. 994-1000.

Fralix, M., J. Langford, C. Carrere, and T. Little,1990: "Reflections on Modular," *Bobbin*, April, pp. 60-66.

Gilbert, C., 1988: "Tracking Modular Production," *Apparel Industry Magazine*, April.

Holoyda, O., 1992: "Quick Response Applications of Technology Enable U.S. Apparel Companies to Improve Competitiveness," *Industry, Trade, and Technology Review*, October, pp. 8-9.

Kron, P., 1987: "Pondering Modular," Apparel Industry Magazine, August, pp. 70-80.

Kulers, B. and J. Dewitt, 1990: "Modular Goes Mainstream," Apparel Industry Magazine, May, pp. 44-52.

Schroer, B. and J. Wang, 1992: *Simulation Support Environment for Modular Manufacturing Systems* SSE5, UAH Research Report 92-03, University of Alabama in Huntsville, October.

Schroer, B. and M. Ziemke, 1992: *Modern Apparel Manufacturing Systems and Simulation, Handbook.*, University of Alabama in Huntsville.

Schroer, B., J. Wang and M. Ziemke, 1992: "A Look at TSS Through Simulation," *Bobbin*, July, pp. 114-119.

Schroer, B., 1990: "Using Simulation Before Implementing a Unit Production System," *Bobbin*, November, pp. 110-114.

Tyson, T., 1996: "MSFC Technology Transfer Program," Presentation to the Technology Transfer Society, Huntsville, AL, January.

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