Proceedings of the 1995 Winter Simulation Conference
ed. C. Alexopoulos, K. Kang, W. R. Lilegdon, and D. Goldsman

A MICRO SAINT MODEL OF CONVEYOR MANAGEMENT STRATEGIES

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ABSTRACT

This paper discusses a simulation project that assessed the cost-effectiveness of modifying a highly complex conveyor system. An automobile component manufacturer was attempting to increase plant capacity by incorporating a dynamically programmable conveyor system. The question was whether the large investment would be justified by the increase in plant capacity. To answer this question, Micro Saint simulation models were constructed and validated for the baseline conveyor system. Then, these models were used to evaluate increases in throughput and utilization that would be gained by different scenaria in 1) different conveyor programming strategies, 2) increases in conveyor demand, and 3) changes in conveyor demand variability. The results of the study indicated that plant capacity would be increased with a dynamically programmable conveyor systems, but perhaps not enough to warrant the investment.

1 INTRODUCTION

In recent years there has been a great increase in the use of simulation as a means of evaluating manufacturing investment alternatives. Many companies investing in expensive advanced manufacturing technologies are using simulation as an essential technology to support the decision making process. Additionally, computer simulation can be used to plan operating strategies for both new and existing systems since it provides means of investigating alternative manufacturing scenarios.

Dunlop Cox Ltd., designs, develops and manufactures vehicle seats and seat mechanisms including slides, reclines, height adjusters, seat frames and fully trimmed seats. The company, located in Nottingham, England, is known especially for its fully integrated seat mechanisms, which are available as either manually or electrically operated units. In order to meet the needs of the 1990's automotive industry, the company has made heavy investments over the recent years. The factory is structured on flow line, cellular manufacturing basis and it operates using Just In Time principles. The company is committed to TQM (total quality management), a philosophy concerned with continuous improvement. To provide total customer satisfaction, Dunlop Cox works in partnership with its customers, and therefore is highly responsive to changes in customer demand and product mix.

As part of this attention to quality and efficiency, simulation was chosen as one of the tools to improve the performance of the factory. Of particular interest was the conveyor and paint plant that was used in the manufacturing process since this was becoming the limiting factor on total plant productive capacity. Several conveyors are used to transport seat components on carriers (flight bars) from the production cells to the paint plant, which can be described as a bottleneck of the factory, and back to the cells again. The aim of the project was build a model which could then be used as a tool to discover ways that the conveyor hardware, software, and or usage practices could be changed to improve the efficiency of the plant.

Of particular interest in the study reported here is the use of dynamically programmable flight bars. The current system used a movable bolt on each flight bar to indicate the assigned production cell. An alternative was to make an investment in a hardware and software system that would allow the allocation of flight bars to production cells to be dynamic as the requirements of the cells vary on a moment-to-moment basis. However, this would require a substantial investment. The question addressed in this study was how great an increase could be obtained by this potential investment. Because of the complexities of the conveyor system, as will be described below, the only viable means for analysis was with simulation.

2 THE CONVEYOR SYSTEM

The ten production cells at Dunlop Cox Ltd. share common paint plant facilities. Several conveyors transport the seat components from the cells into the paint plant, through the painting process and back to the cells again for assembly. The overall layout of the conveyors is illustrated in the Figure 1. At each structure, components are manually loaded onto load jigs hung form carriers (flight bars), which stop on a siding conveyor. From here they are released manually onto the main factory conveyors when the operator pushes the release button. A flight bar takes the components throughout the entire system and returns the painted components to the siding of their home cell, where they are unloaded and new parts take their place.

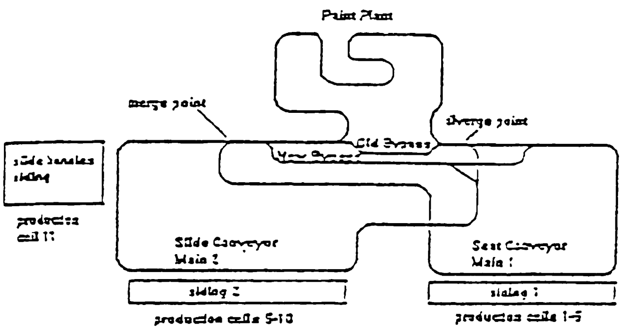

Figure 1: Overview Layout of the Conveyor System

To add to the system's complexity, there are two main conveyors in the system, each dedicated to one half of the factory. The conveyors merge before the paint plant and diverge again after the painting area as shown in Figure 1. The paint plant itself has its own conveyor. There is a siding conveyor on one side of the shop for five cells, four of which are involved in production and one in maintenance. The other half of the factory has two siding conveyors, one for five adjacent production cells and the other for a remote cell which requires a different siding structure. The conveyor system also has many other small aspects of operation that are too lengthy to mention here but are important to the efficient operation of the system. These aspects of the system have evolved over several years and are important contributors to plant performance and, as such, needed to be included in the simulation analysis.

Each cell has a number of flight bars allocated to it and no other flight bars can enter the cell. The conveyor control system is able to direct the flight bars into the correct cell by sensing the fixed bolt on the side of the bar. The investment being considered was a method of dynamically allocating flight bars to each cell during the course of operations based upon moment-by-moment supply and demand.

3 THE SIMULATION PROJECT

The steps followed to build the simulation and answer the question of "Would a dynamically programmable system be worth it?" were as follows:

- define the system to be modeled
- build the model
- collect data
- validate the model
- run experiments using the model
- revise the model and repeat experiments

Below, these steps are discussed as they were followed in this project.

Defining the System to be Modeled: Some previous work done on modeling the conveyor system provided a starting point for the Micro Saint modeling effort. This was supplemented with the plan of the electrical services layout of the conveyor system. Additionally, we make frequent visits to the company. Conveyor maintenance personnel also turned out to be helpful in gathering information about the system.

Building the Simulation Model and Collecting Data: Once a general understanding of the conveyor system had been attained the model was developed and tested gradually using the Micro Saint computer modeling system. The first version of the model including only one of the two factory conveyors and the paint plant. The model was extended as progress was made in developing the conveyor logic and collecting information about the system.

Once the building of the physical structure of the conveyor system into the model was completed, the main concern was how the system is operated by each individual cell. To ensure that the model adequately represented the real system, it was necessary to study the behavior of each individual cell by interviewing the cells leaders. The following
aspects of each cell's behavior were included in the simulation:

- shift working hours
- beginning/end of shift practice (actual period of loading/unloading the flight bars)
- flight bar allocation
- maximum number of flight bars that fit onto the siding
- number of operators (loaders)
- criteria to release an empty flight bar

The development of the logic for dynamic flight bar allocation was carried out during the last stages of model development. The strategy used for assigning flight bars dynamically was based upon input from the Managing Director of the plant as well as insights gained during model development. Also, during model testing, insights for better allocation schemes were gained and subsequently implemented in the model that was used for experimentation.

As we were gaining this knowledge and data about the system, we were concurrently building and refining a Micro Saint model of the system. In the Micro Saint model of the system, the conveyors are represented as chains of tasks, which are sections of the conveyors. Tasks form the top level network diagram of which the final version is shown in Figure 2. Some of these tasks were actually decomposed into subnetworks in the final model.

The model simulated:

- the flight bars as they flowed through the system
- all flight bar queuing and release rules as in the actual conveyor
- routing based upon the system logic (which could be readily changed in the model)
- the potential for dynamic flight bar allocation to the work cells

All aspects of the model were able to be simulated within Micro Saint. The flight bars were treated as tagged entities. Individual attributes could be assigned such as the work cell to which the flight bar was assigned and the status of the current load of painted items on the flight bar. Using this approach, we were

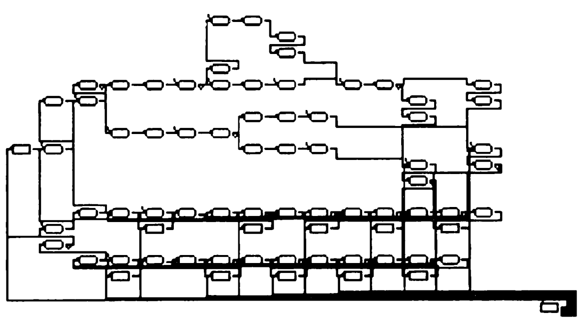

Figure 2: Micro Saint Network Diagram

able to change from a fixed flight bar allocation scheme to a dynamic flight bar allocation scheme by evaluating relevant system parameters (e.g., the queue of items to be painted at each station) and then reassigning flight bar attribute values based upon any logical allocation scheme considered. Different allocation schemes could be tried simply by changing a Micro Saint function. An example of a dynamic flight bar algorithm is presented in Figure 3.

Data generated by the model included 1) the percentage utilization of the paint plant, 2) the number of loaded flight bars that were painted per unit time, 3) the number of flight bars that went through the paint plan either empty or with the same load twice, and 4) the average flight bar cycle time.

Validation and Verification: Throughout model development, validation and verification practices were carried out on a continuous basis. The validity of the model was improved as knowledge of the system increased through several interviews and visits to the shop floor.

Experimentation: The behavior of the model in eight different scenarios was studied varying three factors, 1) the existing fixed flight bar allocation systems vs. dynamic flight bar allocation, 2) the current production rate vs. a 25% increase and 3) a consistent material flow onto the conveyor vs. a variable material flow.

Results: The simulation results are presented in Table 1. The first three columns of this table describe the experimental condition. The fourth column of the table titled "paint plant utilization" is an aggregate

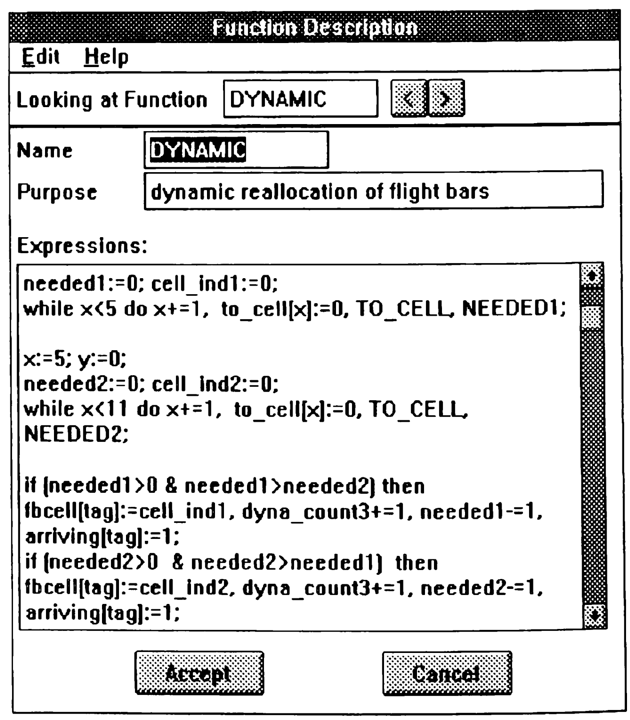

Figure 3: An Example of a Dynamic Flight Bar Allocation Function

measure of the number of cells in the paint plant vs. total paint plant capacity if used 24 hours/day. Utilization of the paint plant remains at around 50-60% because the shut-down hours are included in calculations. The fifth column entitled "number of painted flight bars" shows to the number of flight bars painted excluding empties and those flight bars going through the process twice. When a flight bar is either painted empty or painted twice because the cell was full upon return of the flight bar, this is reported in the sixth column titled "number of flight bars painted empty/twice." The seventh column refers to the overall average cycle time of the flight bar. We were also able to plot measures over time, allowing comparisons such as that shown in Figure 4.

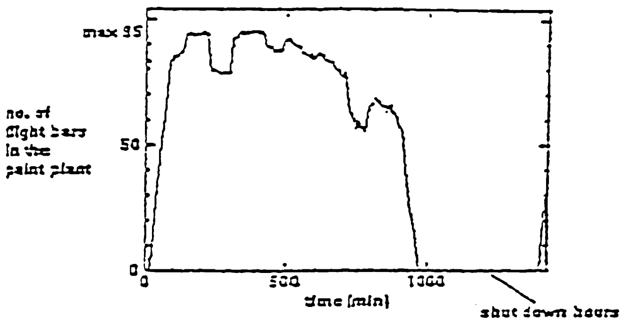

Figure 4: Example of a Graph of Paint Plant Utilization Over Time

4 DISCUSSION OF THE RESULTS

With the existing flight bar allocation, output goals are not fully achieved in the +25% production models. Using a dynamic flight bar allocation scheme gave somewhat better output figures, but the number of loaded flight bars released still did not reach the necessary value to sustain this production rate.

The logic used for dynamic flight bar allocation resulted in some improvements to the operations of the conveyors. The dynamic flight bar allocation decreased the proportion of empty flight bars compared with that of all four scenarios in the fixed allocation models - the current and +25% production models with and without material flow variations. There were significantly fewer empties released from the sidings and the flight bars passed by the home cell more rarely. Thus, the results indicate a more efficient use of the conveyors is possible.

However, the increased formation of queues in +25% production models, especially the one at the end of the slide conveyor, occurred even in a greater extent in dynamic flight bar versions compared with that of fixed allocation models. Hence, final conclusions about the usefulness of dynamic flight bar allocation cannot be made without a more detailed consideration of the queuing effects and potential modifications to the flight bar allocation scheme.

5 SUMMARY

In all, this study provided both useful data and insights regarding the potential effectiveness of a significant capital improvement to the Dunlop Cox conveyor system. Of course, the decision to implement the dynamic flight bar allocation scheme will take into account many other factors such as projected demand, other potential plant limitations, and business constraints. However, this study did provide the

Table 1: Statistics Generated by the Simulation

Production level	Material flow variation simulated?	Flight bar allocation scheme	Paint plant utilization	Number of painted flight bars	Number of flight bars painted empty/twice	Average flight bar cycle time
Current	No	fixed	52.64	946	45	98.5
		dynamic	50.69	948	5	97.7
	Yes	fixed	52.64	946	45	98.5
		dynamic	50.59	948	5	97.7
Current +25%	No	fixed	61.67	1138	24	127.3
		dynamic	61.67	1147	15	130.8
	Yes	fixed	61.51	1122	37	119.7
		dynamic	61.67	1147	15	127.6

decision makers with valuable projections on which these decisions can be based. Additionally, if the scheme is implemented, the simulation model can be used to fine-tune the allocation scheme at virtually no cost.

ACKNOWLEDGMENTS

This work was completed while Dr. Laughery was on assignment at the University of Nottingham, U.K.

AUTHOR BIOGRAPHY

K. RONALD LAUGHERY JR. received his Ph.D., in Industrial Engineering at the State University of New York at Buffalo. He established Micro Analysis and Design in 1981, managing contracts for the development of computer modeling and simulation languages, the design and evaluation of training simulators, the development of supporting technologies for constructive and distributed simulations, and the development of tools for the Army MANPRINT program. Additionally, he participates in developing a number of simulation models for the Army, Air Force, and private industry.