

MANAGING LARGE SCALE MATERIAL FLOW SYSTEMS IN SIMULATION

Osman Korkmaz
Demet C. Wood
Ali Gunal

Production Modeling Corporation

Three Parklane Blvd. 910W, Dearborn, MI 48126, USA

Key Words: Discrete simulation, material flow, manufacturing, PROMODEL

Abstract

In simulating material flow systems, due to the large number of entities and inventory related parameters involved, computer memory utilization, the simulation run speed and managing input and output are the major issues. In this paper, we introduce an innovative approach to resolve these issues. We devise a simulation model that utilizes variable arrays to depict parts and inventory related parameters to increase the memory efficiency and simulation run speed. Furthermore, this simulation model lets users input large number of inventory related parameters in a user-friendly environment. In this paper we discuss the implementation of our approach in an assembly plant setting.

I. Introduction

In automotive industry, the efficiency of material handling systems and the inventory control systems is one of the most important factors of productivity (Black et al. 1996). These two systems are closely related since they effect each other's performance. In this paper we use the term *material flow systems* to represent the integration of the material handling and the inventory control systems.

In this study, our objective was to devise a tool, to be used at a tractor assembly plant, which will enable users to analyze the effects of material flow system parameters on productivity. Due to the large number of entities and inventory related parameters involved, conventional simulation approaches are inefficient (Ulgen, Shore, and Grajo 1994, Jayaraman, Green, and Gunal 1995, Jeyebalan and Otto 1992). The major issues that arise in conventional simulation approaches are computer memory utilization, the simulation run speed and managing input and output parameters. In this paper, we used simulation with an

innovative approach to resolve these issues. Our approach not only manages vast amount of data efficiently, but it also, provides a clear and easy to understand visual output.

We devised a simulation model that utilizes variable arrays to depict parts and inventory related parameters to increase the memory efficiency and simulation run speed. We also designed an interface that allows users to input a variety of parameters to the simulation model easily. This interface also summarizes the output variables of interest in a clear format.

In this paper we discuss the implementation of our approach in an assembly plant setting. This plant produces 3 tractor types and has a total of 125 stations divided in four major production areas each with a dedicated intermediate storage area. Stations carry separate inventories for each product type to be assembled. The parts arrive to the plant through a single dock following a predetermined schedule. They are stored at the corresponding intermediate storage area before they are sent to their stations. Such a setting typically yields overwhelming number of entities which not only uses excessive memory but also reduces the simulation run speed.

Simulation model of this type of settings require large amount of input parameters and dynamic visual feedback of output values. Some of these input parameters are re-order-point, re-order quantity, lead time and arrival schedule. Some of the output values that need to be updated dynamically during simulation are number of tractors produced per shift and per day at the assembly lines and number of parts of each type at the intermediate storage areas and at the stations.

In the next section we describe the material flow system and our simulation model in detail. In Section 3 we explain our approach. Finally, in Section 4 we discuss our conclusions.

II. Material Flow System

In the system we study, materials flow between a dock, intermediate staging areas and individual stations with the use of forklifts. Each station belongs to one of the four assembly lines: weld, cab, chassis, or final assembly. Each assembly line has its own intermediate staging area and a forklift crew.

The material handling system supports 125 stations in four assembly lines. At each station one major part is assembled on to the tractors. Therefore, each station has three dedicated inventory bins; one for each product type. These bins are replenished from the assembly line's own staging area by the line's own material handling crew.

The parts arrive at a single dock with a predetermined schedule. Parts are shipped from the dock, as requested, to the corresponding staging areas by the dock crew.

Each bin at each station has its own reorder level, consumption rate, reorder quantity, and replenishment time. When the inventory level at a bin reaches its reorder level a signal to the staging area crew is sent. Then the staging area crew replenishes the bin with the station's reorder quantity within its replenishment time. The orders from the bins are satisfied in a first in first out manner by the crew. In the case that requested part is not available in reorder quantity the crew processes the following orders until the whole quantity becomes available.

Similarly each staging area has its own reorder level, reorder quantity, and replenishment time for each part it carries. Inventory at the staging areas is replenished when it reaches its reorder level, by the reorder quantity within its replenishment time by the dock crew.

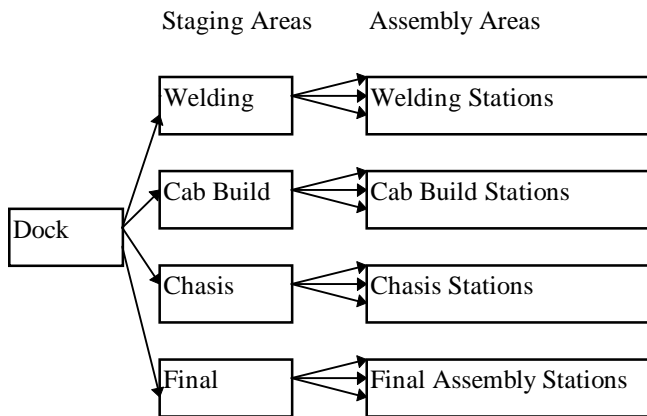


Figure 1. Material Flow Areas

Figure 1 depicts the areas of material flow in this plant.

III. Our Approach

In this section we describe our approach, for analyzing this system, in two parts. First we describe the simulation model, then we describe the interface.

III.1. Model

PROMODEL 3.0. was selected by customer as a simulation modeling tool.

In the system described above there may be 200 tractors and over 10000 parts waiting to be assembled to the tractors, at a given time. Representing all these parts and tractors as entities in most simulation packages would either cause them to crush or to perform very inefficiently. However, in our case, for a realistic analysis, we only need to know the quantity of each part type at each inventory point at a time, average time the line was stopped due to a part shortages and the part that was short. Therefore, in our approach we used variable arrays to represent the quantity of parts at inventory points, rather than representing each part as an entity. Only the tractors are represented as entities.

For each assembly line, we use an [NX6] array for each tractor type where N is the number of stations at that assembly line. Six columns of this array represent station number, current inventory level, consumption rate (number of parts per tractor), reorder quantity, reorder level, and replenishment time. The current inventory level is decreased by consumption rate of the station when a tractor visits the station. If the inventory level is less than the consumption rate, tractor waits at the station until inventory level reaches the consumption rate.

When the current inventory level at a bin reaches its reorder level, a dummy entity is created. This entity first waits until a crew member is available. It then occupies the crew member for the replenishment time duration and increases current inventory level by replenishment quantity and releases the crew member. Afterwards, the dummy entity exits the system.

Inventory replenishment at the staging areas from the dock is handled in a similar way. We used an [MX5] array for each staging area where M is the number of parts carried at that staging area. Five columns of this array represent part number, current inventory level, reorder quantity, reorder level, and replenishment time.

Parts arrive to the plant with a user defined schedule. Another array is used to record the inventory level at the dock.

III.2. Interface

This analysis tool was developed for users with limited knowledge of simulation packages. Therefore it was essential to develop a user interface within an environment where experiments can be performed for a variety of

scenarios with a little effort. The users chose EXCEL as the preferred user interface environment. In this section, we discuss input and output interfaces we developed with EXCEL.

III.2.1. Input Issues

Users can input parameters to PROMODEL using this EXCEL spreadsheet. The parameters that need to be input are selected so that experiments can be conducted with a wide range of variability. The input interface is organized in ten different sheets in one file as follows: one for general information, one for each of the staging areas, one for each of the assembly lines, and one for the dock.

In general information sheet, user can input daily number of each tractor type to be produced, each assembly line's cycle time and other production parameters that are not pertinent to the material flow system.

Each of the staging area sheets allows user to input initial inventory level, re-order point, re-order quantity and replenishment time for each part.

In each of the assembly line sheets, user can input inventory level, consumption rate, reorder quantity, reorder level, and replenishment time for each part type for each station.

Finally, in the sheet of the dock information user inputs delivery days and quantities for each part. Delivery quantity for each part is assumed to be fixed for each delivery day. Therefore user only needs to indicate the days of delivery and a single delivery quantity for each type.

In order to give the users a high level of flexibility in experimentation a vast amount of parameters needed to be input through the interface. We divided the input parameters in categories and kept them in separate sheets to make the interface more usable. This way we achieved an interface that is easy to use, update and manage. Users of each assembly line can experiment with the model by easily updating the corresponding sheet while keeping the rest of the data at its base value.

II.2.2. Output Issues

Users of this analysis tool are interested in keeping track of throughput per shift and day, number of part shortage occurrences and their lengths, and finally average time tractor spends in the system as well as in each assembly line. We therefore developed an output interface with EXCEL spreadsheet where users can obtain the above mentioned values. Furthermore, we also, plotted a timeseries showing throughput per shift for each assembly line. This way, users not only see the average throughput but also observe the variation between shifts and interactions between assembly lines.

Furthermore, the users have a choice to watch the simulation model while it is running and observe some of the output parameters. The parameters depicted on the screen are inventory levels at each station at each bin as well as the average throughput per shift and the average time a tractor spends in each assembly line.

In addition, PROMODEL provides a vast amount of built-in statistics such as resource and location utilization, entity utilization, for advanced users, at the end of each run.

IV. Conclusion

In this paper, we devised a flexible simulation tool to analyze material flow dynamics of a plant. First, we developed a simulation model of the plant to depict the major activities. We used arrays to increase the model size as well as the speed of the simulation runs. Then, we developed a flexible user interface to conduct experiments for different scenarios. Using arrays to depict the parts in a material flow system is well justified by the advantages that we have gained. Using arrays, we were able to increase not only the number of parts and tractors that we can simulate but also, the run speed of the simulation model. In addition to speed and size, initiating part's inventory at each storage area as well as modeling the new rules become very easy. Lastly, using arrays for parts enabled us to develop an easy and clear run time visual output to see the inventory level at each storage area. However, using arrays lacks the convenience of utilizing built-in functions of PROMODEL such as, utilization of parts, animation of parts, and average time that an entity spends time in the system.

REFERENCES

- Black, J., Bulat, J., Colwell, B., Combs, R., Potvin, H., "Simulation in Automotive Industry - Today and the Next Five Years," Panel Session Chaired by O. Ulgen, Proceedings of the Autofact Conference, SME, Dearborn, MI, November 1996, pp. 947-961.
- Jayaraman, A., J. A. Green, and A. K. Gunal, "Continuous Improvement Applied to Simulation Modeling: A Case Study," Proceedings of Winter Simulation Conference, 1995, pp. 930-935.
- Jeyebalan, V. J. and N. C. Otto. 1992. "Simulation of Material Delivery Systems with Dolly Trains." In Proceedings of the 1992 Winter Simulation Conference (Arlington, VA, Dec. 13-16). IEEE, Piscataway, N. J., 916-924.
- Ulgen, O., Shore J., and Grajo, E., "The Role of Macro- and Micro-Level Simulation Models in Throughput Analysis," ORSA/TIMS Joint National Meeting, Detroit, Michigan, 1994.