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

COMBINING SIMULATION AND SCHEDULING: AN APPLICATION IN THE OFFICE FURNITURE INDUSTRY USING ARENA AND PREACTOR

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ABSTRACT

This paper describes the combination of a proprietary finite capacity scheduling package, PREACTOR 200, with the ARENA simulation package to provide a day-to-day scheduling tool for the assembly of office furniture by a company in Austria. The keyword of this project is "Factory in a Factory," or FIF, which denotes how the assembly facility is broken down into sub-units that are responsible for assembling different types of furniture. Previously ARENA had been used to model the interactions that occur within each FIF (labor, buffer space, access to the conveyors) and ensure that product arrived at the right time to the delivery area at the end of a main conveyor so that containers (that are used to transport orders to different locations around Europe) could be filled in the correct sequence. It was clear from this preliminary work that sequencing of product assembly in each FIF and load leveling, whereby the number of operators in each FIF could be changed according to product mix, were key to the functioning of the facility.

1 INTRODUCTION

The company produces a wide variety of office furniture, about 1 million variants. Product is delivered to different locations in Europe using steel containers that hold all the products for the location. As orders arrive, they must be broken down into products that will then determine the amount of work to be completed by each FIF. The scheduler must then decide the number of operators to use in each FIF to handle the load and the sequence of container loading. As each container load must be completed and placed on the main conveyor before product is loaded for subsequent containers, the utilization of personnel in each FIF will change from one container to the next. This requires that labor be reassigned between container loads or internal buffers or space must be available in an FIF such that the next container load can be started earlier.

PREACTOR 200 is a low cost finite capacity scheduling tool that was developed in a EUREKA project (an initiative funded by European governments to develop technology through collaboration by companies and academic institutions in different countries) that has many automatic scheduling features such as forward, backward and bi-directional. Most importantly, it can be linked easily to other packages such as MRP systems, sales order processing systems, and simulation packages such as ARENA. However, as it cannot deal with all the constraints of the real system, the features of PREACTOR were used to carry out much of the work and then the project group loaded the container sequence into the ARENA simulation model to ensure that the schedule was achievable using all the constraints of the system. Because a model of the system had already been developed in an earlier stage of the project, all that was required was to add some functionality to PREACTOR, deal with the transfer of data, and create the right reporting mechanisms.

2 THE ASSEMBLY SYSTEM FIF

The assembly system is designed to be simple and practical with very little automation and uses the flexibility of human resources to the fullest. The assembly system is shown schematically in Figure 1. It consists of 10 FIF's, each with the same area of around 15m x 30m. Completed assemblies are transferred by a conveyor to a main or spine conveyor that transfers the loads to the point where the products are loaded into containers. Other characteristics are:

- A wide variety of products are assembled in the system.
- Ten FIF's are located along one main conveyor with their own areas of responsibility.
- A maximum of three pickup stations for ten FIF's along the main conveyor.

- Assembled parts of the same order for each container must be available at the pickup stations in a redefined quality.
- A limitation of internal buffer size in each FIF.
- Assembled furniture of the same order move in succession on one main accumulating conveyor to the loading area where they are loaded into containers.
- A large number of human operators must interact in such a way that the assembly system operates efficiently.
- A maximum of 30 containers has to be loaded per day with a due time no later than 4 PM.
- The order sequence of all FIF's is defined between the human operators by a so-called "boundary position agreement."
- The inspected and assembled furniture is taken over by the inspection personnel and loaded onto the main conveyor. This is done on the "transfer plates."
- There is a central significance of all "FIF pickup stations" along the main conveyor which defines the schedule.
- The inventory has to be at a minimum.

Figure 1 shows the top view of the assembly line with the individual department's FIF, and on the left-hand side is the loading area with four containers.

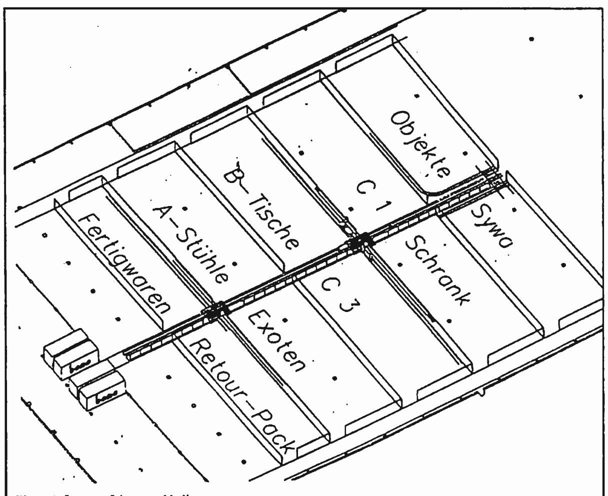

Figure 1: Layout of the assembly line

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Figures 2 and 3 show two different FIF's in operation and the roller conveyor for assembled furniture. The size of these roller conveyors determines the maximum buffer capacity in each individual FIF. Depending on the type and size of individual articles, these are loaded by the operators onto the pallets, called furniture dogs.

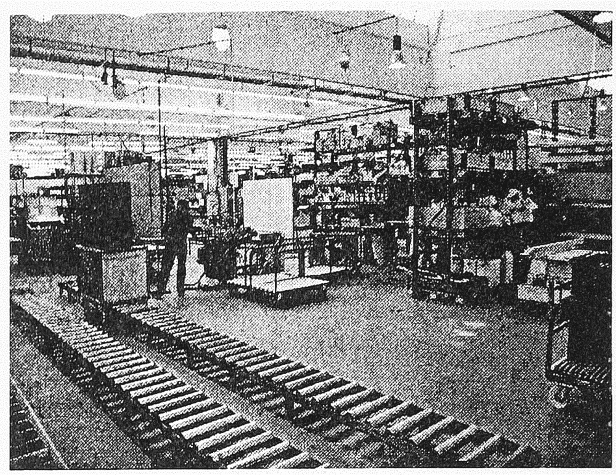

Figure 2: FIF SS and Roller Conveyor

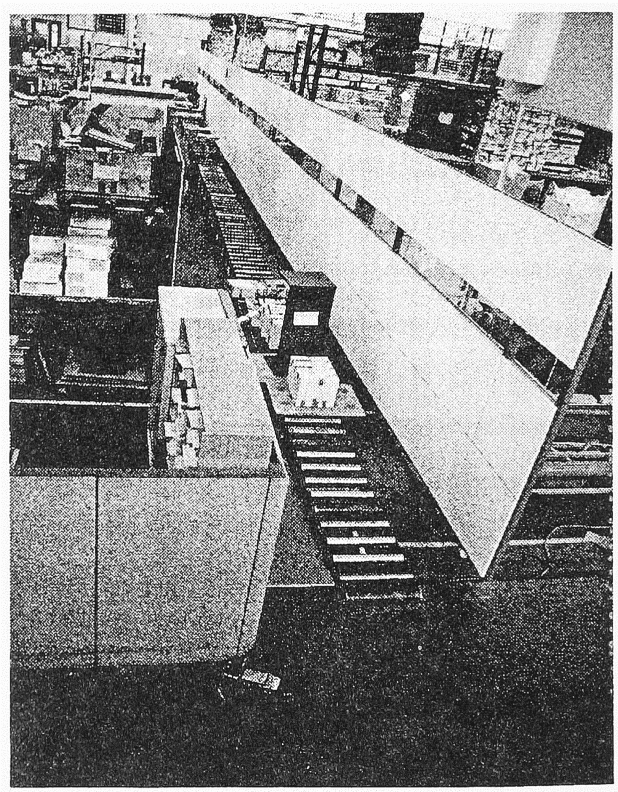

Figure 3: FIF C3 and Assembled Furniture

3 SCHEDULER OPERATION

The installed system provides both rough-cut capacity planning on a finite capacity basis using PREACTOR (some people refer to this as fine-cut capacity planning) and detailed analysis of interactions in each FIF. Nine days before the orders are to be shipped, information is read into PREACTOR from the company's AS400 computer. The first task carried out is "load leveling," whereby based on the number of operators available and the daily mix of products to be assembled, PREACTOR attempts to allocate operators to each FIF so that the overall load during the day is the same in each FIF. Forward or backward scheduling of containers can then be carried out with the start time and end time for each container in each FIF decided by the longest processing time of the bottleneck FIF. Further runs can then be made to overlap start and end times so that a maximum utilization of operators can be achieved and so there is a minimum overall "makespan" for the day. Once the user is satisfied and has tried many "what if" alternatives, the information is passed to the ARENA model to test the effects of the other constraints of the system, such as buffer space, conveyor space, inspectors, loading personnel, etc., and assure that this does not cause a conflict in the delivery of finished items to the container loading area. Once this is complete, information on operators, the sequence of furniture to be built, etc., can be printed out as work-to lists for FIF.

4 CUSTOMIZATION OF PREACTOR

PREACTOR 200 was modified for this application to meet the specific requirements. PREACTOR can be configured by the user using two ASCII files. The modules are described below.

- **Order Input Module**

This module loads data on the containers to be scheduled from the AS400 into PREACTOR's database. Three files are generated automatically:

- TOURxx.RAW, information about the containers
- STATICxx.RAW, information about the individual articles; e.g., assembly time, size, number of pallets required
- EAUFxx.RAW, information about product mix, individual parts to be assembled, etc.

- **Container Pre-Sequencer Module**

This module generates different priorities for containers corresponding to the rule selected from a menu:

1.	CLWLF	Container with the lowest workload first
2.	CHWLF	Container with the highest workload first
3.	CLWLOF	Container with the lowest workload over all FIF's first
4.	CHWLOF	Container with the highest workload over all FIF's first
5.	CLWWLOF	Container with the lowest weighted workload over all FIF's first
6.	CHWWLOF	Container with the highest weighted workload over all FIF's first
7.	CLWLT	Container with the lowest weighted loadtimes first
8.	CHWLT	Container with the highest weighted loadtimes first
9.	CLRLTWL	Container with the smallest rate loadtime/workload first
10.	CHRLTWL	Container with the highest rate loadtime/workload first

This module also generates the number of operators for each FIF for the container overlapping option. In this case, the manning level in each FIF is constant over the whole day.

- **Container Sequencer Module**

This module uses data read into PREACTOR by the Order Input Module to rank containers in order of priority. The priority is determined using different rules selected from a menu. There are three different classes of containers:

1. Truck external containers, "A" (picked up by a carrier during the day)
2. Train containers, "B" (must be loaded on the train no later than 5 PM)
3. Truck internal containers, "C" (delivered by the internal carrier)

- **Load Leveling Module**

This module provides for manual and automatic load leveling by changing the number of operators in each FIF for each order within a container. In this way, the minimum time window for each container is obtained. Information on the maximum number of staff for each FIF is entered. An additional feature is also included whereby the number of staff is not a constraint but the maximum time window can be defined.

- **Container Overlapping Module**

This module tries to overlap FIF portions of all containers for both options—forward and backward scheduling. The goal of this option is to overlap the containers in such a manner that all containers can be loaded in time without changing FIF personnel during the day.

- **Order Sequencer Module**

This module allows the user to try different methods of sequencing orders for each FIF during the day. Taking the earliest start time and latest finish time from the load leveling module, the user can backward or forward schedule work orders to obtain the best combination for each FIF.

- **Reports and Plots Module**

The reporting facilities work in the same way in all the PREACTOR modules, and the user is automatically given the reporting options for the file or database that is currently being edited/viewed. The available reports are:

1. Orders: A complete list of all the orders in the system
2. Work-to List: Individual work-to lists for all FIF's by day
3. Route Cards: Routing information for each batch of work
4. Job List: Lists all jobs and operations, by day or all together
5. Tardy Jobs: Lists the jobs and operations that are late

In addition, plots can be generated showing the manning levels of each FIF over time. The user-defined variable plots can be displayed from the plots option in the sequencer. Figure 4 shows the manning levels for a certain order sequence of six FIF's.

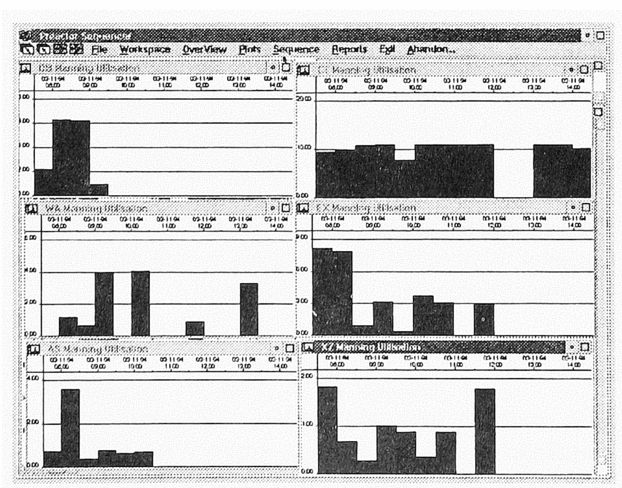

Figure 4: Plots of Manning Levels

The Gantt Chart in Figure 5 displays the sequenced articles belonging to individual containers with start and end times over a one-day production period.

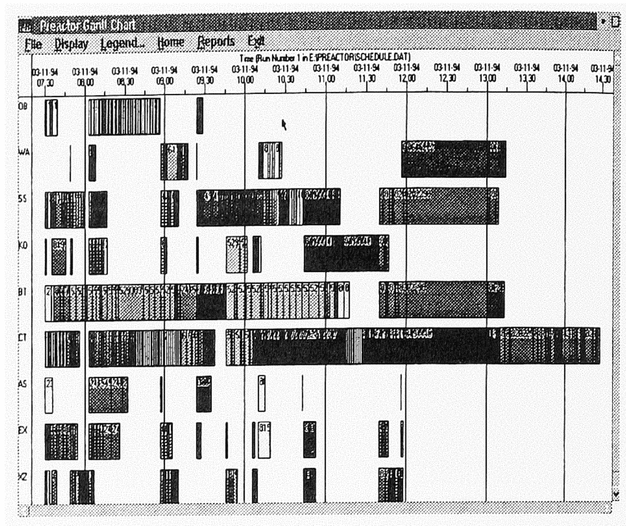

Figure 5: Gantt Chart of Sequenced Articles

5 THE ARENA SIMULATION TOOL

ARENA is a graphical modeling/animation system that provides a complete simulation environment. It supports all basic steps in a simulation study. ARENA is based on concepts from object-oriented programming and hierarchical modeling (Drevna and Kasales 1994). ARENA allows the user to create new modeling modules from basic modeling primitives that consist of SIMAN blocks and elements. The assembly line model was developed using ARENA. This enabled the complex constraints of the real system to be studied in the first instance and then to use the SIMAN model generated by ARENA to link to PREACTOR to provide high-speed generation of achievable schedules using the data generated by PREACTOR. See Figure 6 for the ARENA animation layout of the assembly line.

The simulation model consists of the following basic modules:

- **Data Input Module:** (reads in data from the PREACTOR database system)
- **Initialization Module:** (initializes the resources (operators) in the animation)
- **Material Flow Module:** (operators, buffers, conveyors, loading station)
- **Data Output Module:** (this data is transferred to PREACTOR after every simulation run)

After every simulation run, the user can compare container finishing times generated by PREACTOR with those delivered by the simulation. The results of the simulation give the user insight as to what impact buffer sizes of each individual FIF, transfer and inspection times, bottlenecks of the main conveyor and order mix have on the performance of the assembly line.

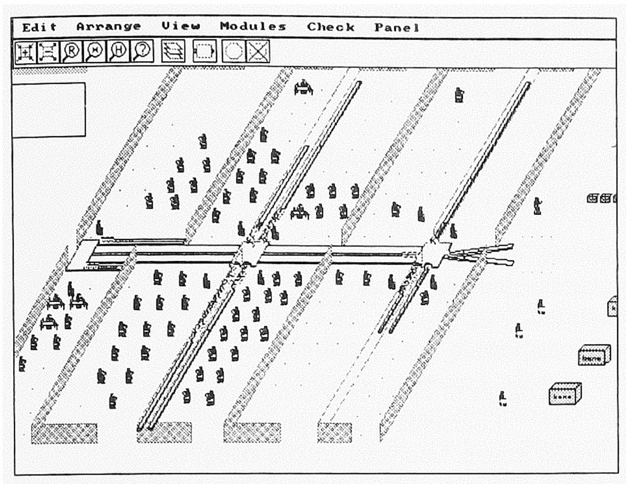

Figure 6: ARENA Animation Layout of the Assembly Line

6 SUMMARY

The paper describes how an "algorithmic" finite capacity scheduling tool, PREACTOR, has been linked to a simulation package, ARENA, to provide a fast and effective decision support tool for day-to-day management of a production facility. In particular, it describes how PREACTOR is being used as a "filter" to carry out "what if" testing of alternative scheduling rules and then this is passed to a simulator for detailed analysis where, for example, utilization is high, delivery tight, and constraints are complex. This combination provides the user with a tool that is fast to use (even on what is, by today's standards, a relatively slow PC), easy to maintain, and linked to existing data sources.

REFERENCES

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