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USING SIMULATION TO SCHEDULE MANUFACTURING RESOURCES

Hank Czarnecki
Bernard J. Schroer
M. Mizzanur Rahman

University of Alabama in Huntsville
Huntsville, Alabama 35899, U.S.A.

ABSTRACT

This paper discusses a real-world application of simulation to schedule operator and machine resources in a floor tile manufacturing plant. The paper discusses attempts at using a spread sheet, a simulator, and finally ProModel in the scheduling process.

1 INTRODUCTION

There is considerable interest and research in combining capacity planning, scheduling and discrete event simulation in the manufacturing environment. Capacity planning is the process of determining the tooling, personnel, and equipment resources that are required to meet customer demand. Scheduling is the time-sequenced allocation of these resources. Traditional methods of capacity planning and scheduling have used infinite capacity and static time calculations. Quite often the results are inaccurate and non-representative solutions to very important questions (Thompson, 1993).

2 LITERATURE REVIEW

As an example of on-going research, Drake and Smith (1996) have formulated a framework for on-line simulation in the planning, scheduling and control of manufacturing systems. Their simulator allows for the input of different scheduling rules and is written in SIMAN. Kunnathur et al. (1996) have developed a rule based expert system which is driven by a simulation model for dynamic shop floor scheduling.

A real world implementation of simulation and scheduling has occurred at the AMP+AKZO Company where eighty percent of customer delivery requirements change weekly (Flower and Cheselka, 1994). As a result, enormous amounts of work-in-process have resulted in delays and long throughput times. AMP+AKZO is using a simulation based finite capacity scheduling system with WITNESS.

3 PROBLEM

Figure 1 is a layout of the manufacturing line for a tile manufacturer in Alabama. The plant covers 400,000 square feet and has 150 employees. The manufacturing line consists of the following stations:

- Two extruders which make “green” tiles from clay and place tiles on finger carts
- Eighteen dryers which dry the “green” tiles
- Two setting machines which places tiles on kiln carts
- Two kilns which cure the tiles
- Two finishing stations which final inspect and package the tiles

An increase in customer demand has caused problems in scheduling work on the factory floor. As a result, additional shifts have been added by the tile manufacturer to increase production. However, because of the wide variation in station cycle times, the additional shifts have resulted in increased work-in-process and have further exposed the bottlenecks in the manufacturing line.

3.1 TAKT TIME

One approach to the scheduling problem is to understand TAKT time (Stewart et al., 1997). TAKT is a German word for pace and is the rate at which the customer requires product. TAKT time defines the manufacturing line speed and the cycle times for all manufacturing operations. TAKT time is computed as:

$$\frac{\text{Available work time per day}}{\text{Daily required demand (units/day)}}$$

Ideally cycle time for an operator or station should be

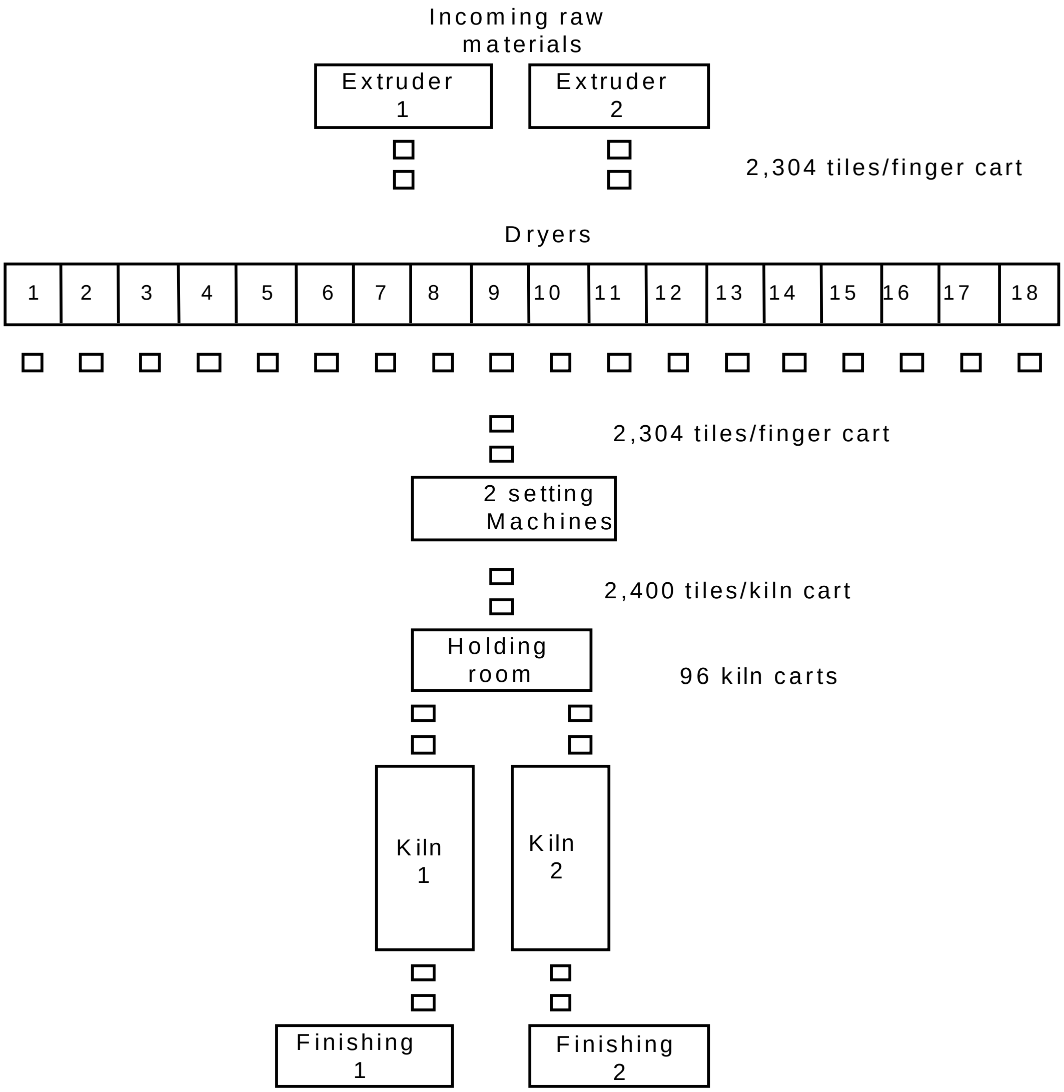

Figure 1: Tile Manufacturing Facility

close to but not exceed TAKT time. If the cycle time is less than TAKT time, the operator can keep pace. If the cycle time is greater than TAKT time, the operator cannot keep pace. When the operator cannot keep pace, the available work time must be increased such as adding overtime or a second shift. If the available time cannot be increased, efforts must be made to eliminate wastes in the process or additional or faster equipment may be required to meet customer demand. When customer demand changes, it may be necessary to re-calculate TAKT time and to reallocate operator tasks.

For example, Figure 2 gives the operator cycle times for a manufacturing line. The horizontal line is the TAKT time of 11 seconds/unit to meet customer demand. Operators A, C and D have a TAKT time less than eleven seconds and can meet demand. Operator B has a TAKT time greater than eleven seconds; therefore, this operator and consequently the plant cannot meet demand. One approach is to reallocate the work content among the operators so that each operator's work content equals or is slightly less than the TAKT time. A second approach is to look at the seven wastes of manufacturing, to evaluate the operations and operators, and to identify opportunities for improvement which would reduce cycle times. The seven wastes of manufacturing are waste of overproduction, waste of waiting, waste of transportation, waste of processing, waste of inventory, waste of motion, and waste of making defective items (Ohno, 1988).

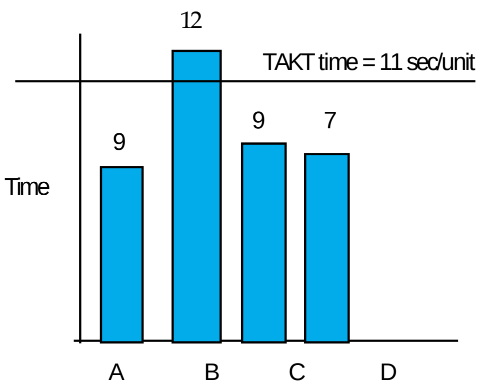

Figure 2: Operator Work Content

3.2 Approach

There were several solutions available to the floor tile manufacturer. One solution, and generally the most expensive solution, is to purchase additional machines for those stations causing the bottlenecks. Another solution is to schedule more hours, if available, for those stations causing the bottlenecks. The latter solution requires either working overtime or hiring additional operators for a second and or third shift.

Management selected the station scheduling option over purchasing additional equipment. The first attempt to scheduling was the development of a spread sheet to analyze the various station schedules. Although the spread sheet did provide an answer, the spread sheet lacks the flexibility to rapidly modify the schedule based on a change in customer demand.

The second attempt to scheduling was a call by the tile manufacturer to the NASA Marshall Space Flight Center's (MSFC) Technology Transfer Office in Huntsville, Alabama. MSFC provided a copy of the Modular Manufacturing Simulator (MMS) which was developed by the University of Alabama in Huntsville (Schroer, et. al., 1996). The MMS is a simulator for designing and analyzing manufacturing lines. MSFC also referred the manufacturer to UAH for further assistance. After several calls, a simulation model was developed using the MMS that provided management with much needed information on the maximum capacity of the line. However, the MMS could not provide production statistics as a function of a specific station schedule.

The third attempt to scheduling was a follow-up call by the manufacturer to the Region 1 Center of the Manufacturing Extension Program at the University of Alabama in Huntsville. Staff at the Center developed a simulation model of the manufacturing line using ProModel. ProModel was selected because of a feature that allows the input of a schedule for each station in one minute intervals of the day and by day of week. Therefore, it was possible to quickly evaluate the impact of a new schedule on production.

4 MANUFACTURING LINE

The operational characteristics of the manufacturing line in Figure 1 are given in Table 1. Tile is moved on carts between the stations. Finger carts, used for the extruders, dryers and for input to the setting machines, have a capacity of 2,304 tiles. From the setting machines through finishing, tiles are placed on kiln carts with a capacity of 2,400 tiles per cart.

Table 1: Operational Characteristics

Station	Number of Machines	Capacity	Cycle time
Extruder	2		64 tiles/minute
Dryer	18	7 finger carts per dryer	36 hours
Setting	2		64 tiles/minute
Holding	1	96 kiln carts	
Kiln	2	30 kiln carts	23 hours
Finishing	2		80 tiles/minute

Because of the increased customer demand, management's objective was to maximize throughput through the line while minimizing direct labor hours per type of machine. Sine the dryers and kilns run continuously, management determined that these stations must be staffed continuously. Therefore, schedules only had to be determined for the extruders, setting and finishing stations.

Using the results from the Modular Manufacturing Simulator, TAKT time was set at 31.3 minutes, which equates to 322 kiln carts per week with 10,080 available minutes. Figure 3 gives the cycle times for each station compared to TAKT time. Downtown ranged from 15 to 40 percent and included changeovers, scheduled and unscheduled maintenance, and waiting for materials for the extruding, setting, and finishing stations ranged from 15 to 40 percent. The manufacturer’s strategy to meet TAKT time was to reduce the available hours on the extruding, setting and finishing stations.

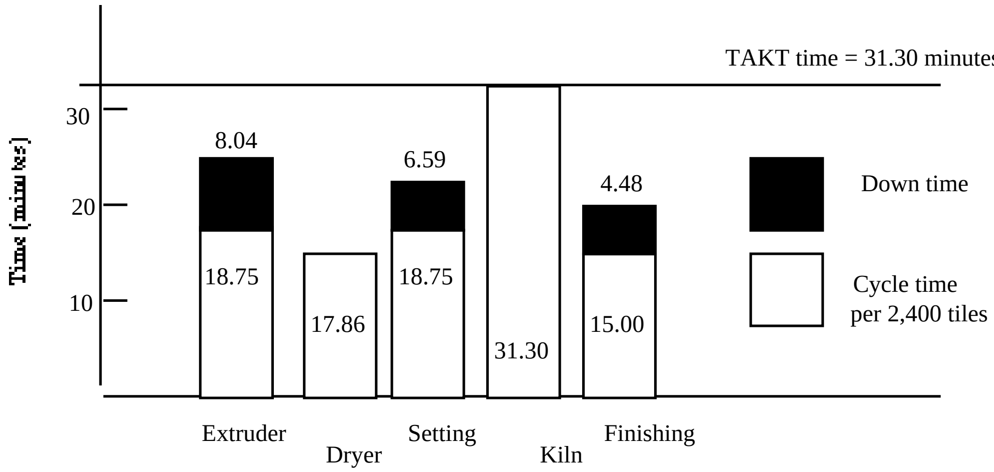

Figure 3: Cycle Times For Operations

5 SIMULATION MODEL

The Modular Manufacturing Simulator was used to approximate the maximum throughput of 322 kiln carts per week. This was verified using an unconstrained simulation without shifts and downtime. Operations prior to the extruders included the delivery of clay and processing through the crushers. There was sufficient capacity and WIP to ensure a constant supply of clay to the extruders.

The basic logic of the simulation model is given in Figure 4. Schedules are defined for each of the stations. The schedules can be defined to one minute intervals. The schedules are then entered into the simulation model along with the parameters of the manufacturing line. Next the model is executed and the results analyzed. The schedules can then be modified and the model run again. Ten replications were made with a warm-up period of one week and was run for a one week planning horizon.

A more detailed description of the simulation model is given in Figure 5. No downtime or shifts were associated with the kilns, therefore the capacity and cycle time for the kilns determined the throughput for the line. The finishing operation has excess capacity that could be scheduled to process all of the tile from the kiln without impacting throughput. Thus, the simulation model was decomposed into how to optimally schedule the extruders and setting operations to maximize throughput.

Iterations were made to the schedule for the extruders while holding the schedule for the setting machine constant to determine the minimum number of hours needed to maximize throughput for the line while at the same time maintaining a constant supply of kiln carts in the holding area. Figure 6 contains the average throughput and holding area content as a function of various schedules for the extruders. Management chose the schedules which had a throughput of 322 kiln carts. This was the schedule of 133 hours or more. From these schedules the contents of the holding area remained constant. Since the model was initialized with 30 kiln carts in the holding area, the schedule of 133 hours maintained the 30 kiln carts.

Once a schedule was determined for the extruders, the same methodology was used for the setting station. Figure 7 contains the average throughput and holding area content as a function of various schedules for the setting machines. The schedule of 137 hours maintained the 30 kiln carts.

Figures 8 and 9 contain the optimum schedules for the extruders and the setting stations which maintained the desired 30 kiln carts in the holding area. The schedules are by hour of day for a seven day work week. The white boxes in the figures are non-scheduled work time. The black boxes are break time. The light gray boxes are the work times. These schedules were the input to the simulation to determine production.

6 CONCLUSIONS

In summary, the following conclusions are made:

• The manufacturing plant had sufficient capacity to meet customer demand.

• The simulation provided management with the schedule and hours required at each station to achieve maximum tile throughput.

• Using the simulation model, management can now plan for preventive maintenance. Also, management can adjust to daily fluctuations in customer demand through the use of overtime.

• The ProModel feature of defining station specific schedules was ideally suited for the floor tile manufacturer's scheduling problem. By varying the station schedules it was possible to obtain a schedule which met customer demand and minimized labor.

• The simulation model was written and operational in eight hours.

• Staff from the manufacturer visited UAH Manufacturing Extension Center and were trained in the use of the model in six hours.

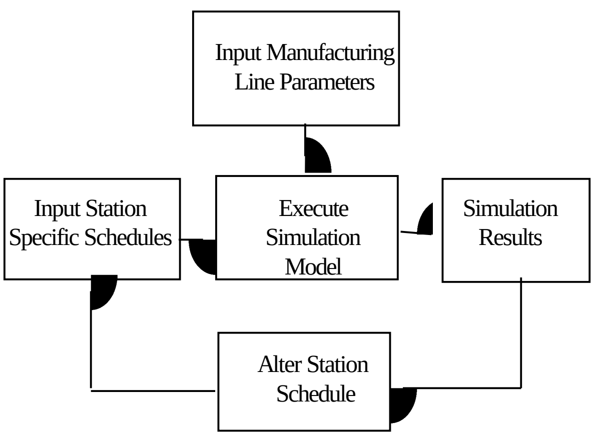

Figure 4: Overview of Simulation Model

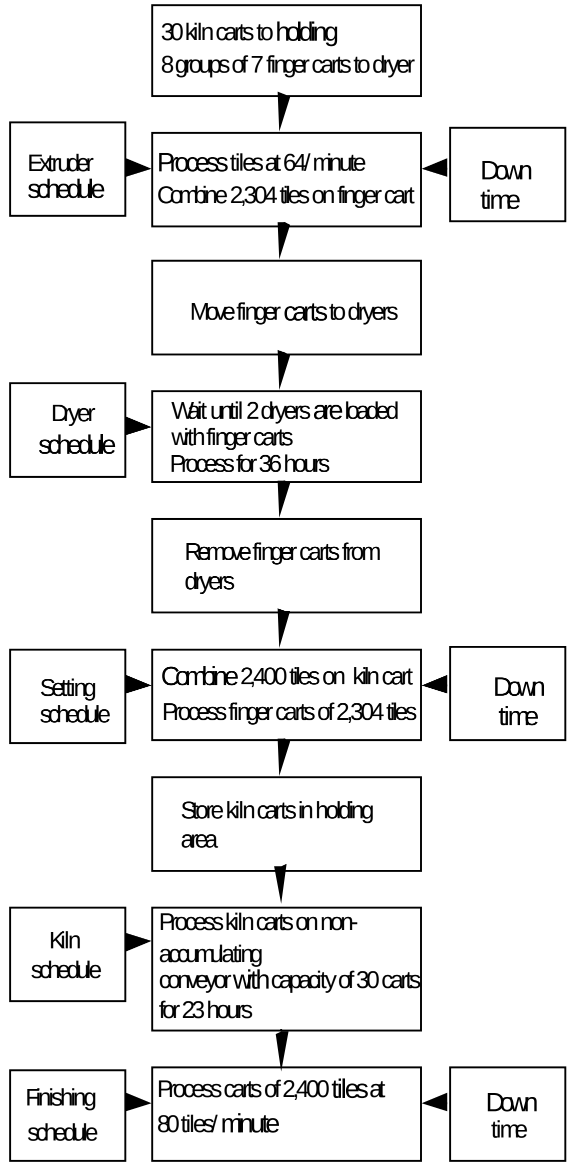

Figure 5: Detailed Simulation Model

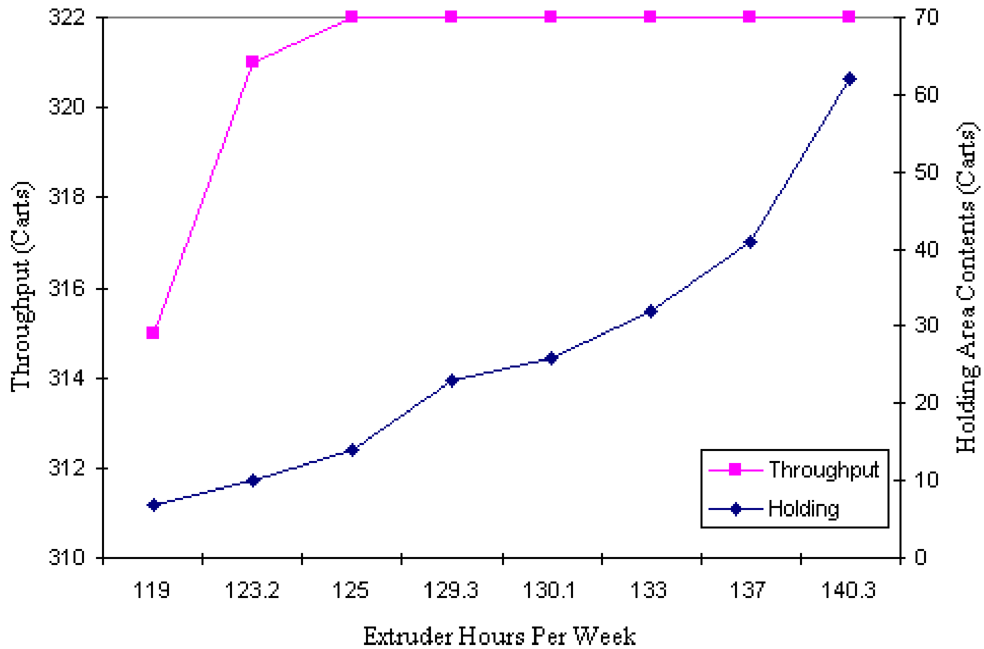

Figure 6: Average Throughput And Average Holding Area Content Versus Extruder

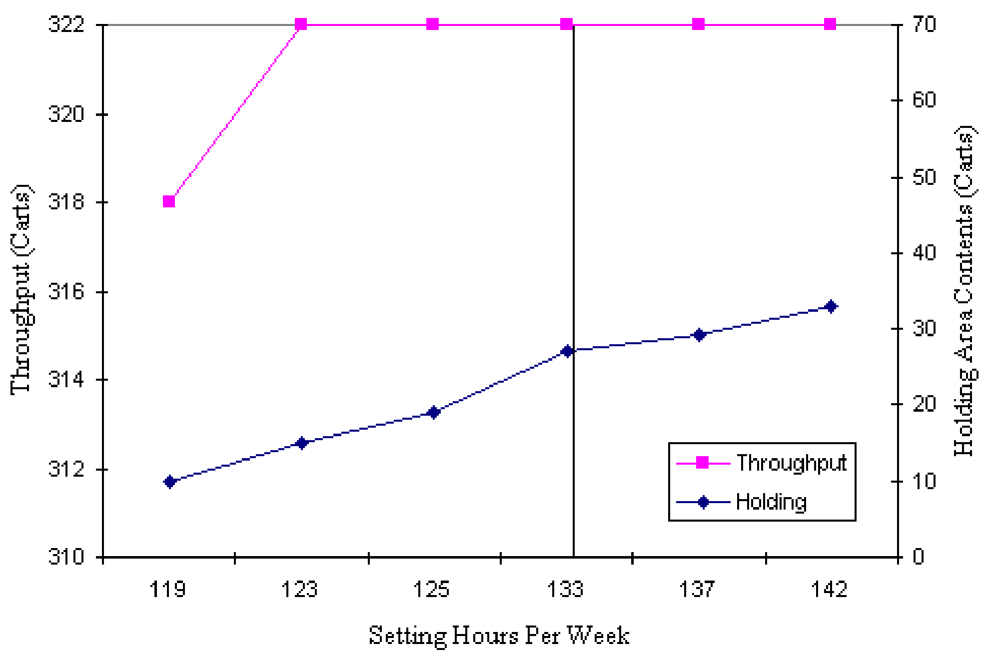

Figure 7: Average Throughput And Average Holding Area Content Versus Setting Hours

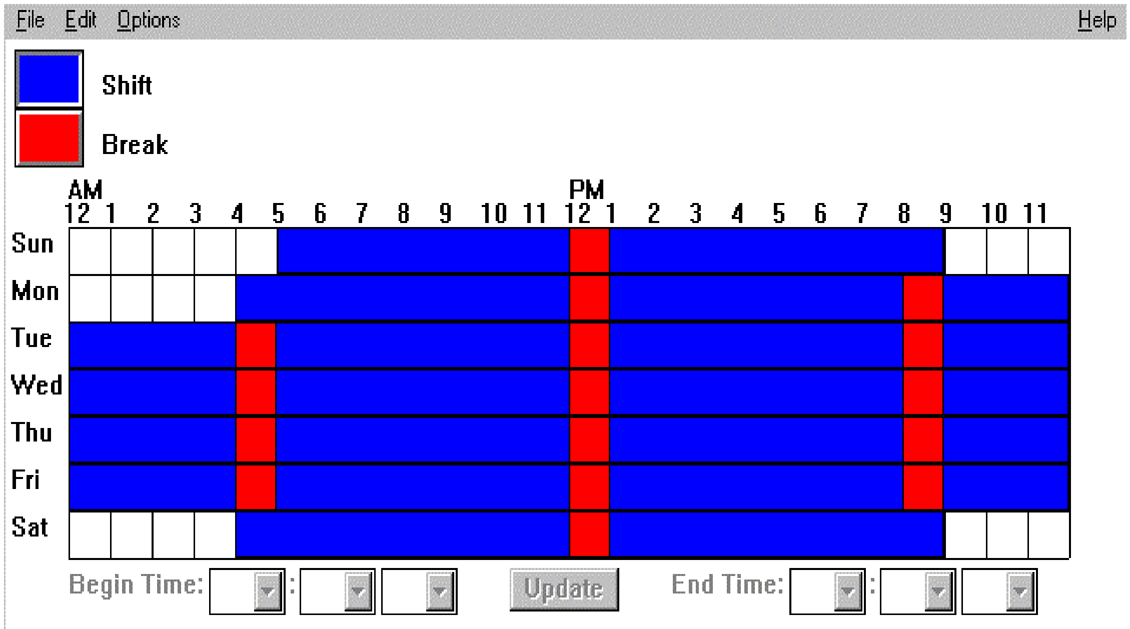

Figure 8: Optimum Schedule For The Extruders

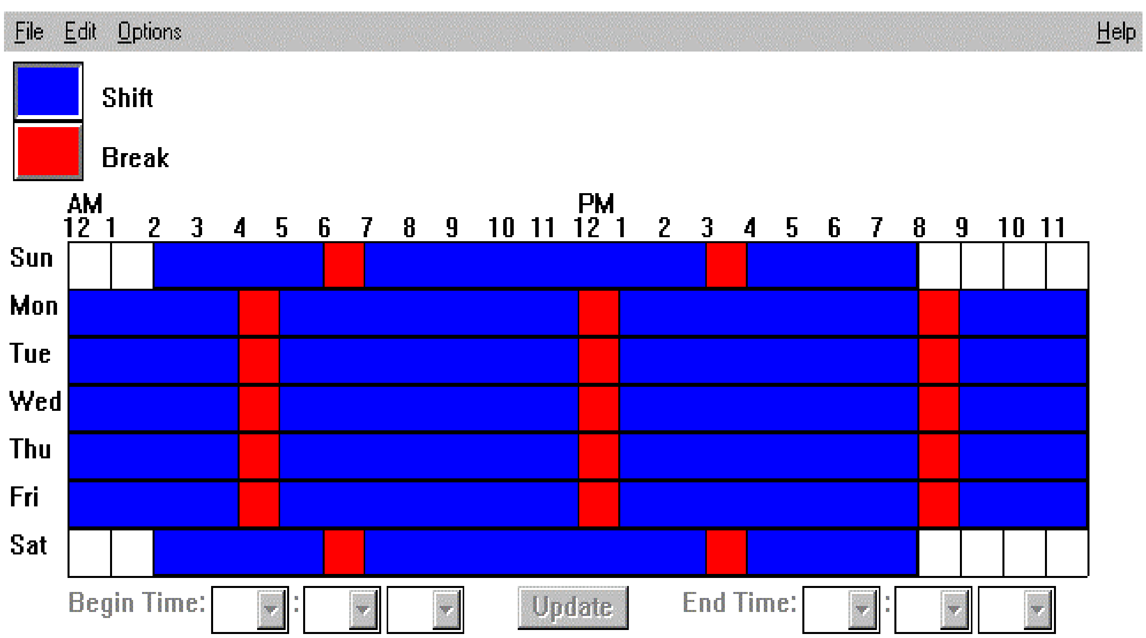

Figure 9: Optimum Schedule For The Setting Stations

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AUTHOR BIOGRAPHIES

HANK CZARNECKI is a Senior Research Associate in the Center for Automation and Robotics at the University of Alabama in Huntsville. He has a M.S. in Industrial Engineering from Auburn University and is pursuing a Ph.D. in IE at UAH.

BERNARD J. SCHROER is Director of the Center for Automation and Robotics and Professor in Industrial and Systems Engineering at the University of Alabama in Huntsville. He has a Ph.D. in industrial engineering from Oklahoma State University, a fellow of IIE and a member of NPSE, SCS, ASEE and the Technology Transfer Society.

M. MIZZANUR RAHMAN is an Associate Professor in Industrial Technology at Alabama A & M University in Normal, Alabama and is on the staff of the UAH Manufacturing Extension Program. He received his Ph.D. from the University of Alabama in Huntsville. He is a member of IIE and APICS.