*Proceedings of the 1991 Winter Simulation Conference*
*Barry L. Nelson, W. David Kelton, Gordon M. Clark (eds.)*

# TUTORIAL: SCHEDULING MANUFACTURING SYSTEMS WITH FACTOR

David Krahl

Pritsker Corporation
1305 Cumberland Avenue
West Lafayette, Indiana 47906

## 1 ABSTRACT

This tutorial covers the basic concepts of FACTOR version 5.0 as applied to scheduling a production facility. Topics include: the FACTOR 5.0 modeling constructs, integration with existing production data, and the use of FACTOR for schedule creation and adjustment.

## 2 SCHEDULING AND SIMULATION

Scheduling in most manufacturing facilities is currently performed assuming no limits on the capacity of the manufacturing personnel and equipment. Because of the ease of modeling limited resources, simulation is able to provide more accurate and detailed schedules and performance estimates than traditional methods. Traditional simulation tools, however, have not been designed to handle the specific requirements of a scheduling application. These include: the ability to load the current manufacturing system status including the actual orders being processed, providing accurate, detailed equipment, material, and personnel schedules, and providing the required simulation results before they become out of date on the manufacturing floor. In addition to these requirements, scheduling software must be able to interface directly with existing production control systems to allow automated data transfer, both in to and out of the scheduling tool. Finally, results must be presented in a manner which is easily understandable by shop floor personnel who most likely will not be familiar with traditional simulation terms analysis.

## 3 FACTOR - SCHEDULING DECISION SUPPORT UTILIZING SIMULATION

FACTOR is a decision support software system which, through the use of a simulation kernel, is able to generate detailed finite capacity schedules, accurate capacity planning information, and on line schedule adjustment. FACTOR is specifically designed to meet the needs of manufacturing production planning. In addition, sufficient flexibility is been incorporated to ensure that the required level of detail can be achieved.

While FACTOR is not a simulation language, a model is built by combining basic modeling components in a way which duplicates the characteristics of the actual system. These model components are stored in a fast access database before the start of the simulation of the production system. This information can be either loaded manually through standardized or customized screen oriented editors or utilities. Input error checking and on line help are available both for the standard system and any user customizable options.

FACTOR output for simulated alternatives is also stored in the database. This allows for transfer of the required information to external manufacturing systems through a user customizable export utility. This output may be generated by the standard FACTOR report generator or tailored to the specific needs of the application and viewed on a computer terminal with a full screen review function.

The FACTOR simulator is coded entirely in the C programming language and uses advanced techniques for rapid simulation execution and schedule generation. Currently FACTOR 5.0 is available on the IBM AS/400 with the schedule adjustment functionality residing on OS/2. FACTOR 4.0 is available on VMS, HP/UX, OS/2, and VM.

## 4 FACTOR MODELING COMPONENTS

FACTOR 5.0 provides an extensive set of standard modeling components for use in building models of production systems. The major components include:

- Order Characteristics
- Shop Floor Status
- Production calendar
- Shift Schedules

- Resources
- Functional Resource Groupings
- Resource Maintenance
- Parts
- Materials
- Process Plans

Resources are either classified as single capacity resources (FACTOR resources) or multiple capacity resources (pools). FACTOR resources are generally used to model personnel and manufacturing equipment which can be on a shift, subject to maintenance, or for which schedule information is desired. Multiple units of a resource are modeled by making a FACTOR resource a member of a resource group. A resource requirement for an operation is thus listed as the resource group rather than any of its members. A variety of resource group member selection rules including user customizable rules are available. Pools are used to model resources such as a WIP area for which no schedule, maintenance, or shift is required. FACTOR includes a number of the most commonly used scheduling rules and a convenient interface for installing user defined logic.

FACTOR process plans provide details on how and in what order operations are performed on a part. A process plan consists of a sequence of jobsteps with provisions of a standard and alternative routing at each point. Each jobstep can require one or more resources, resource group members, or pools. The processing duration may be defined at the jobstep as fixed for the entire load, pre piece or calculated in a user function. The major FACTOR jobsteps include:

- Operation
- Setup/Operation
- Setup
- Move
- Move Between
- Assemble
- Produce
- Inspect
- Batch
- Add to Material
- Remove from Material
- Accumulate and Split

In addition to these jobstep types, the modeler may create specialized modeling components of their own design. User defined components include: jobsteps, resource sequencing rules, jobstep durations, resource group member selection, and alternative jobstep selection rules.

## 5 DATA INTEGRATION CAPABILITIES

One of the major factors in the success of a scheduling system is the integration of the scheduling software with existing production data systems. Accurate schedule generation depends upon accurate production system objectives and status at the beginning of the simulation. The ability to import information from other sources with speed and ease is critical to the success of a scheduling product.

Although it is possible to enter all of the required data to generate a schedule manually, to achieve the required level of automation, most data will be placed into the FACTOR database through the use of transfer programs written with tools such as SQL, RPG, or C. If the external manufacturing systems reside on the AS/400 along with FACTOR 5.0, the data transfer operation requires that the necessary information be merely copied into the FACTOR 5.0 database records.

Often the ultimate end user of a scheduling package will be a person with little or no knowledge of the actual inner workings of the software that generated the schedule. It is critical that the information provided by the scheduling package be in a form that is in the language of the person interpreting the schedule on the factory floor. All of the functions must be easily accessible without being burdened with modeling details or data fields for which the shop floor personnel have no control.

FACTOR provides two standard interfaces, the scheduler's interface and the modeler's interface. The scheduler's interface gives the shop scheduler access to information necessary for the creation and evaluation of various scheduling alternatives. In addition to the functionality of the scheduler's interface, the modeler's interface gives the FACTOR modeler access to information necessary for the creation and maintenance of the scheduling model. Both of these interfaces are tailorable to the user's environment. This feature is especially important to the scheduler as it allows the FACTOR information to be presented in a manner consistent with the application environment.

The interface tailoring option also provides the user with the ability to create a totally new interface for either the modeler or the scheduler. The FACTOR software user has complete control over screen content, screen organization, help messages, input checking, and the commands which will be executed for a selected option. It is possible to integrate functions defined outside of FACTOR such as the initiation of a data transfer function. This functionality provides a single consistent interface for the entire scheduling operation.

## 6 SCHEDULING AND SCHEDULE ADJUSTMENT WITH FACTOR

In practice, FACTOR is used to schedule operations on a regular scheduling interval and to handle unexpected events. At the start of the scheduling interval, (shift, day, week...) status information is transferred into the FACTOR database.

The scheduler executes the simulation and reviews a summary of the performance of the schedule. These reports allow the scheduler to detect potential scheduling problems and adjust the parameters of the FACTOR model. The new model is then executed and the two alternatives are compared. This process is repeated until a satisfactory schedule is created. Once an alternative has been accepted, a detailed schedule is generated for the components of interest (equipment, personnel, materials...). This information can be distributed to the operators or automated cell controllers.

Often, one or more unforeseen events may invalidate the current schedule. These events include a machine failure, the arrival of a rush order, or a missed delivery date of a supplier. To react to these situations the FACTOR 5.0 Schedule Management Module (SMM) could be used to interactively adjust the schedule to meet the new system conditions.

The SMM is a graphical scheduling tool which provides a convenient mechanism to review and quickly adjust an existing FACTOR 5.0 schedule. The schedules presented by SMM are in the form of interactive GANTT charts (see Figure 1). The three functions provided by SMM are: schedule viewing, schedule adjustment, and schedule transfer. Schedule viewing displays the current schedule for orders, jobs, and resources allowing the scheduler to quickly review critical information. Schedule adjustment allows the scheduler to react to unexpected changes in the shop floor status by graphically editing the current schedule. Schedule transfer allows the scheduler to transfer the schedule information to and from a machine running the OS/2 operating system where SMM resides to the FACTOR 5.0 database on an AS/400.

The function of FACTOR in the scheduling environment is thus both a tool to generate feasible and achievable schedules as a decision support system for rapid "what if?" analysis of scheduling alternatives. The scheduler is provided with the capability to completely and accurately determine the outcome of a scheduling decision, adjust the schedule to meet the constantly changing shop floor status. This capability is a necessity when scheduling the highly complex production systems in use today.

## 7 THE FACTOR TUTORIAL

The tutorial at the Winter Simulation Conference will provide details about modeling and scheduling with FACTOR. The presentation will include a series of FACTOR screens, details about modeling components, example output reports and a demonstration of the Schedule Management Module. The modeling process will be discussed in detail as will the implementation and integration of the model, and the use of the model for scheduling.

## 8 ADDITIONAL READING


Grant, Floyd H. (1987), Scheduling and Loading Techniques. *Production and Inventory Control Handbook,* Second Edition, Green, J. H., Ed., American Production & Inventory Control Society.

Grant, Floyd H. (1986), Production Scheduling Using Simulation Technology, *Advanced Manufacturing Systems Conference*, IFC (Conferenced) Ltd., 129-138.

*FACTOR Implementation Guide* (1989), Pritsker Corporation, West Lafayette, IN.

*FACTOR Site Specific Tailoring* (1989), Pritsker Corporation, West Lafayette, IN.

*FACTOR User Interface Tailoring* (1989), Pritsker Corporation, West Lafayette, IN.

*FACTOR Information Transfer* (1989), Pritsker Corporation, West Lafayette, IN.

*FACTOR Output Analysis System* (1989), Pritsker Corporation, West Lafayette, IN.

MacFarland, D. G. and F. H. Grant (1987), "Shop Floor Scheduling and Control using Simulation Technology," *Shop Control '87,* Cincinnati, OH.


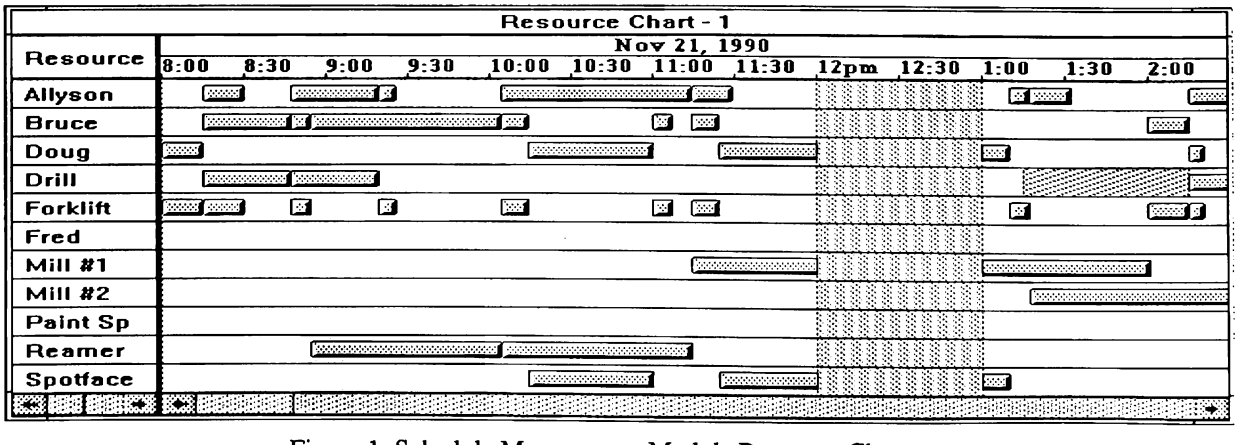


Figure 1. Schedule Management Module Resource Chart

## AUTHOR BIOGRAPHY

**DAVID KRAHL** is a Consultant in the Training and Support group at Pritsker Corporation. He received a Bachelor of Science Degree in Industrial Engineering from the Rochester Institute of Technology. Since joining Pritsker in 1986, he has performed technical support and taught classes in Pritsker software products, developed simulation application for the consumer products, automotive, and aerospace industries, and worked in software design and development.