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MANUFACTURING DECISION MAKING WITH FACTOR

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ABSTRACT

This tutorial covers the basic concepts of FACTOR. FACTOR has been applied to engineering, design, scheduling and planning problems within many manufacturing organizations. Topics covered include: the FACTOR modeling constructs, integration with existing production data, the use of FACTOR for schedule creation and adjustment, FACTOR/AIM, and new enhancements to the products.

1 THE FACTOR SYSTEM

The FACTOR system is designed to support the effective management of the capacity of a manufacturing organization. This philosophy is best described as Total Capacity Management (TCM). The TCM fundamental principle suggests that through a thorough understanding of a systems capacity and the ability to control that capacity, a manufacturing system can profitably and predictably deliver quality product to its customers. Figure 1 shows the functional breakdown of the TCM philosophy. These issues of predictability, profitability, and quality face every manufacturing organization today.

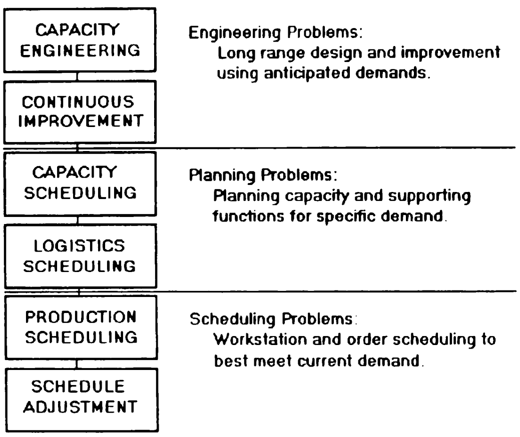

Figure 1. Total Capacity Management Functions

Using simulation to represent the complexities of manufacturing operations provides an accurate representation of the systems capacity. Compared to many of the current techniques that use infinite capacity or bucketized approach, simulation provides a very accurate prediction of system performance and operation. Traditional simulation tools, however, have not been designed to handle the specific requirements of an application integrated to existing manufacturing data systems.

The special requirements for a manufacturing design, planning, and scheduling system include:

- the ability to load the current manufacturing system status including the actual orders being processed,
- providing accurate, detailed equipment, material, and personnel schedules,
- providing the required simulation results before they become out of date on the manufacturing floor, and
- allowing a model of the manufacturing process to be used for design, planning and scheduling.

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 analysis terms.

To address these issues, FACTOR consists of three modules. The FACTOR Simulation System is designed to address the capacity engineering activities of TCM. Models are built graphically and animated directly. Output reports and graphs are designed to analyze the dynamic system performance. The FACTOR Product Manager generates capacity and production plans. It is designed so that it may be easily integrated into existing manufacturing data systems and customized to provide reports that concisely provide information for planners and schedulers in terms they use and understand. The

FACTOR Lietstand is used to create and communicate schedules graphically using a GANTT chart or adjust these schedules. Figure 2 shows the architecture of the FACTOR system and how it relates to the TCM functions.

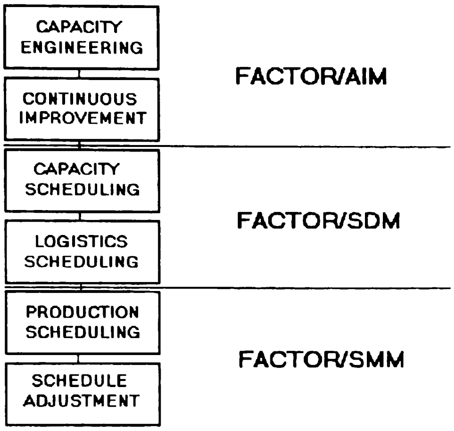

Figure 2. FACTOR Modules

2 PLANNING & SCHEDULING DECISION SUPPORT UTILIZING SIMULATION

FACTOR Production Manager (PM) 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 PM is specifically designed to meet the needs of manufacturing production planning. In addition, sufficient flexibility has 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 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.

Specific sub-modules within FACTOR PM are provided to address specific manufacturing issues. These modules are the PM Order Promising Module, Order Relase Module, and Monitoring and Tracking Module.

FACTOR PM's Order Promising capabilities help manufacturing organizations answer customer service questions. When sales personnel commit to an order they are required to provide a firm ship date. This date depends on the availability of critical shop resources and the mix of product being produced by the facility. Order Promise provides a multi-user system to support the order delivery promise function, necessary in today's competitive environment. Sales personnel interact with the planning and scheduling model to determine if the proposed order can be completed to meet customer needs.

Order Release utilizes simulation and backward scheduling techniques to determine when order should be introduced into the planning and scheduling system. The timing of the release of an order for the factory floor is critical if inventories are to be maintained at low levels and delivery dates are to be met. FACTOR 's PM Order Promising Module combines current order levels, factory floor status, and sequencing strategies (minimize set-up time, maximize throughout, etc.) to best utilize available manufacturing capacity.

Monitoring and Tracking (M&T) helps schedulers and planners check the progress of the factory against plan. M&T provides an up-to-the-minute display of operational status on the shop floor, integrated with a display of the plan or schedule. From this display, supervisory personnel can adjust the timing or sequencing of upcoming events to respond to changes in execution. Utilizing GANTT chart graphics and color coding status conditions, M&T clearly communicates the progress of the orders on factory floor.

3 FACTOR MODELING COMPONENTS

All FACTOR modules are specifically designed to represent complex manufacturing operations. In particular, FACTOR/AIM was designed to represent manufacturing operations from the design and continuous improvement perspectives. AIM capabilities and features have been designed to increase modeler productivity by reducing the amount of time that is required to build models. Modeling detailed manufacturing systems is accomplished by combining the FACTOR/AIM modeling components. The following sections give a brief overview of the AIM modeling approach.

3.1 GENERAL GUIDELINES

The FACTOR/AIM basic modeling components are common to many manufacturing systems. Sample basic modeling components include:

Machines	Operators
WIPs	Parts
Process Plans	Orders
Fixtures	Material Handling Equipment

AIM models are built by defining the capacity constraining resources and the parts that flow through these resources. These resources are most commonly machines, operators, work-in-process areas, and the material handling equipment. Each of these components is represented directly in AIM. Their operation can be modified by selecting alternate operations and decision rules. These resources can also be assigned shifts, breakdowns, and maintenance behaviors. The graphical representation of these resources can be assigned by the modeler and are automatically changed as the state of the resource changes. A sample editor for a machine resource is shown in the following figure.

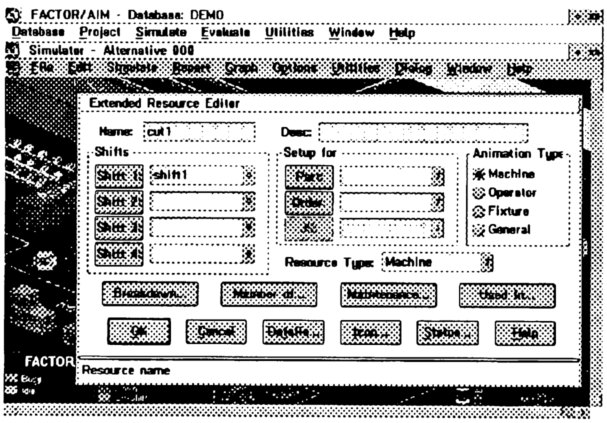

Figure 3. Sample Machine Resource Editor

The logic of the manufacturing system is captured in the AIM model with the Process Plan component. A process plan is a collection of jobsteps. Parts enter the system and follow a process plan. Multiple parts can follow a single plan using operation and setup times from a lookup table. A sample of the types of jobsteps available in AIM include:

Setup	Remove from Material
Operations	Assign a Variable
Produce	Accumulate/Split
Assemble	Inspection
Move Between	User Defined
Add to Material	etc...

The process plan component can represent complex manufacturing systems by combining these jobsteps. At each jobstep the resources defined in the model can be requested, seized, or released. Multiple resource actions can be performed on a single jobstep. The process plan can be thought of as a flowchart describing the flow of parts or part families through the manufacturing process. Existing part routing sheets can easily be translated into FACTOR/AIM process plans.

The parts flow through the manufacturing facility as loads. Loads can be created by several different means. In some models loads are created by using an existing order book or log. Using this approach the modeler loads the actual loading of the system into the AIM order table of the database. This approach supports the modeler that wishes to compare the performance of the manufacturing operations under different configurations using actual production loading. Another method of creating loads is used when modeling pull oriented manufacturing systems. In this type of model the modeler describes the circumstances under which new requests for parts or sub-assemblies are needed by the system. These pull orders generate loads that represent the required parts or sub-assemblies.

Several other methods of load creation exist in FACTOR/AIM. Any model may contain any combination of these load creation methods.

3.2 ADDING MANUFACTURING DETAILS

Each component of AIM can be customized by the modeler by selecting alternative actions and rules. A detail page is available for most component types. For example, a modeler can control how a specific machine chooses the next job to start when it completes a job. Sample rules for jobs requesting this machine can be selected using the following rules.

Adjusted Dynamic Slack	Least No. of Jobsteps
Earliest Due Date	Least Processing Time
Earliest Release Date	Least Static Slack
FIFO	Longest Any Jobstep
High Attribute Value	Longest Current Jobstep
High Priority	Low Attribute Value
Large Load	Low Priority
LIFO	Shortest Current Jobstep
Least Av. Dynamic Slack Per Remaining Jobsteps	Smallest Load
Least Dynamic Slack	Min. Setup Time over
First N Loads	User Defined
etc...	

In this manner the detailed operation of the manufacturing system can be captured. AIM contains over 160 locations where the modeler can choose from alternative actions or rules.

If the built-in rules do not represent the system being modeled, the modeler can create a custom rule to be used. This rule is written in the C language and is compiled and linked to the simulation executive without leaving AIM. Rules are written and used in a manner that they can be created by an expert user and used by less experienced modelers.

3.3 MODELING SUMMARY

Modeling in AIM is done by describing the manufacturing operations to be modeled using manufacturing terms. The preceding discussions provided a brief overview of the modeling components and capabilities. The following figure shows a summary of the AIM components and their relationships.

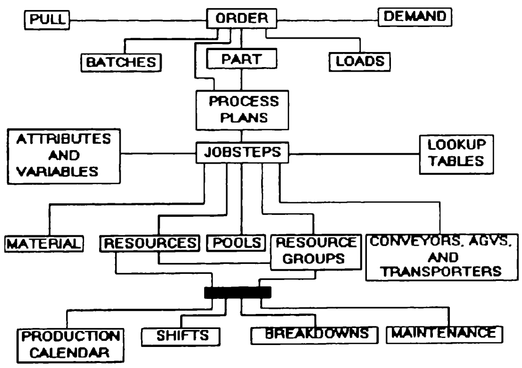

Figure 4. FACTOR Modeling Components

4 DATA INTEGRATION

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 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. The data connections usually associated with a FACTOR Production Manager installation are shown in figure 5.

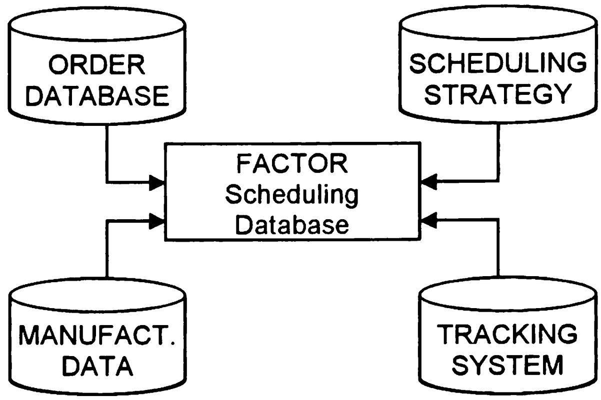

Figure 5. FACTOR Data Connections

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.

5 SCHEDULING AND SCHEDULE ADJUSTMENT WITH FACTOR

In practice, FACTOR Production Manager is used to plan and schedule operations on a regular interval and to handle unexpected events. At the start of the scheduling interval, (shift, day, week...) status information is transferred into the FACTOR PM 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 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 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 5). 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 residing on the AS/400.

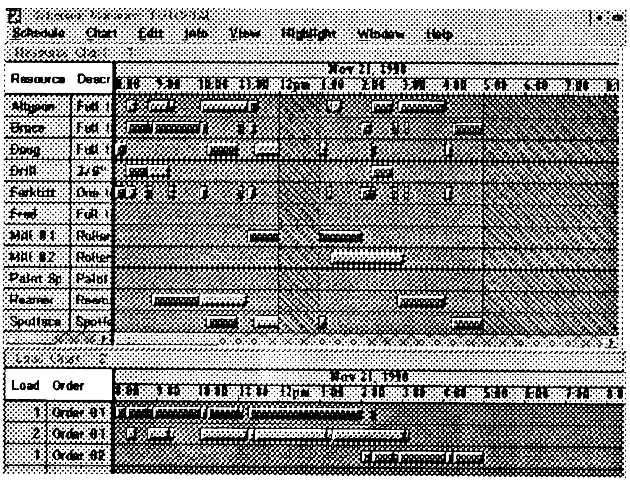

Figure 5. FACTOR/SMM User Interface

The function of FACTOR in the scheduling environment is thus both a tool to generate feasible and achievable schedules and 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, and 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.

6 FACTOR/AIM

The AIM module of FACTOR can be used in an integrated or stand-alone manner. AIM extends the FACTOR modeling components to address capacity engineering problems. Stochastic models can be built in AIM representing the random nature of the manufacturing process. The output reports are also intended to reflect the stochastic nature of the analysis

Model building in AIM is accomplished by graphically placing the capacity constraining resources in a facility window. The placement of machines, operators, buffers, and material handling equipment is all accomplished on this facility window. Details about the components behavior are added through dialog boxes.

A key feature of AIM is the level of detailed manufacturing logic that is build into the product and available without any programming. For example, within manufacturing, a key productivity decision is made every time a machine or line chooses which part to work on when it completes a job. In most simulation tools this choice is accomplished through the implementation of a sequencing rule on the list of requests. Common sequencing rules include FIFO, LIFO, Most/Least Space, Most/Least Free, High Value of an Expression, etc. In AIM the available sequencing rules are manufacturing specific and include due date, high priority, load size, least remaining jobsteps, dynamic slack, release date, etc. Additionally AIM can choose the next part dynamically not simply on the sequencing rule. For example, AIM can select a part to minimize the setup time based upon the job just completed or part, family, and subfamily relationships. All of these capabilities are available in AIM without programming.

Using these built in manufacturing capabilities models of complex manufacturing systems can be built quickly and accurately.

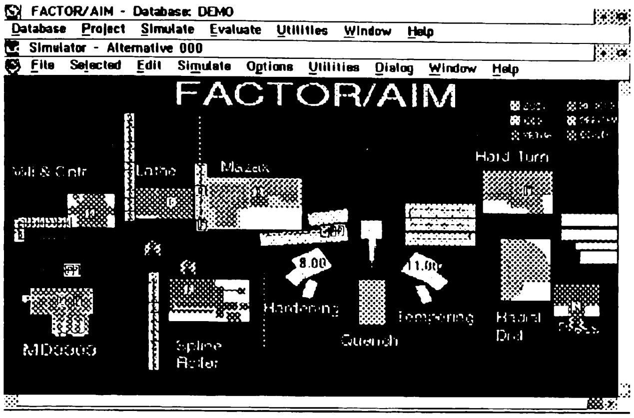

Figure 6. Sample FACTOR/AIM Facility Window

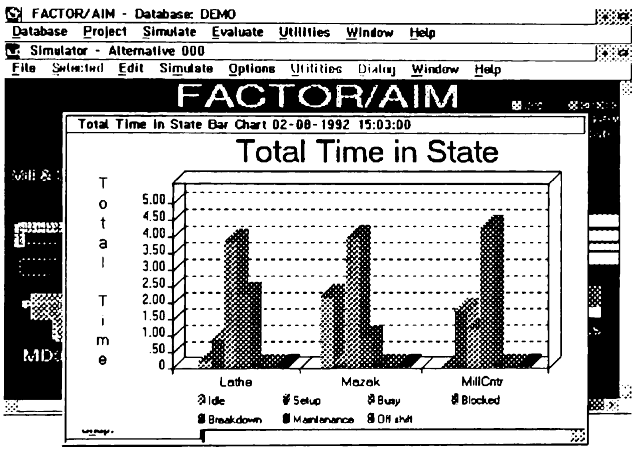

Figure 7. FACTOR/AIM Output Graphics

7 COST MODELING

The latest release of FACTOR/AIM, Version 6.0, extends the manufacturing simulation capabilities to include the modeling of manufacturing costs. Version 6.0 modelers can model cost allocations with simple fill-in-the-blank forms. Modelers create custom cost categories in two general classifications; operational or overhead. Operational costs are allocated to the products produced using an approach selected by the modeler. Standard costing or Activity Based Costing (ABC) can be modeled using Version 6.0. Overhead costs are accumulated over the simulation run and allocated in the same manner as operational costs.

The details of the cost model are created by defining the cost contributors at each step in the manufacturing process. These cost contributors can represent simple relationships including the amount of labor hours expended on a jobstep and then calculating the labor costs considering whether overtime was used. More complex calculations to derive energy costs or complex labor charges are also possible. The outcome of these contribution equations is added to the previous value of the selected cost category. As each load is processed it is generating overhead costs and accumulating operating costs.

Separate output reports and graphs are available in Version 6.0 to communicate the outcome of the cost simulation. The average operating expense per part, the value of inventory, and total expense incurred are just a sample of the reports and graphs available in Version 6.0. Utilizing the custom reporting of FACTOR/AIM it is possible to generate cash flow reports and pro forma income statements from the model.

The cost enhancement to AIM included in Version 6.0 of the software makes it easier to model this important aspect of manufacturing decision making.

8 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/SDM screens, details about modeling components, example output reports and a demonstration of AIM. The modeling process will be discussed in detail, as will the implementation and integration of the model, and the use of the model for capacity engineering, planning and scheduling.

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AUTHOR BIOGRAPHY

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