INTEGRATED PRODUCTION & PERFORMANCE SUITE





FactoryTalk[®] Scheduler



USER'S GUIDE

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Welcome to FactoryTalk Scheduler

Welcome to FactoryTalk Scheduler, the state-of-the-art finite-capacity system that will help you gain control of your production scheduling.

What is FactoryTalk Scheduler?

FactoryTalk Scheduler is a client/server application that is an integrated part of the RSBizWare product suite. FactoryTalk Scheduler allows you to generate a detailed, finitecapacity schedule that provides a view into the future. Through this tool, production schedulers can identify and act on late orders; manage capacities and constraints, including labor and material; and identify the consequences of making changes, like expediting orders. FactoryTalk Scheduler allows total resource management and, most importantly, provides time to react to any unintended consequences.

What is the benefit?

FactoryTalk Scheduler considers all factors that reduce the ability of a production resource to process, including shift patterns, labor/tooling/material availability, planned maintenance, current loading, and capacities. In summary, FactoryTalk Scheduler produces a more accurate and realistic schedule.

How is it designed?

FactoryTalk Scheduler was designed using all of the latest available software technologies. The newest version of FactoryTalk Scheduler is written in Visual C++* with Object Oriented Development. FactoryTalk Scheduler uses the ActiveX* Data Objects (ADO) component of the Microsoft Data Access Components (MDAC) software development kit to provide direct access to various database types. FactoryTalk Scheduler provides direct connections to Microsoft SQL Server and Oracle databases. FactoryTalk Scheduler has incorporated Crystal Reports* for its report writer, which allows you to design and develop your own reports on top of the many standard reports that have already been developed. FactoryTalk Scheduler was designed with a document-view interface that makes it very easy for you to navigate through the screens.

Where do I begin?

You start by creating a model of the resource capacities and capabilities of a production facility considering the scheduling objective(s) of the company. Once your model is complete, you can select the algorithmic or simulation scheduling rules that best achieve the defined objectives. FactoryTalk Scheduler is capable of importing product routings and orders, from which it is simple to generate a detailed schedule. The last part allows

you to check the schedule performance against the defined objectives and adjust the schedule if necessary.

Since FactoryTalk Scheduler was designed to be highly configurable, your installation may look somewhat different from the examples in this guide. The figures and dialogs shown here are based on the tutorial example of a small manufacturing system (BizBikes, Inc.) that produces bicycles, which is included with the FactoryTalk Scheduler software. This example system was selected because it contains many of the key features that are often used in a typical FactoryTalk Scheduler installation.

Intended audience

We assume that you are a manufacturing or production engineer/manager and are familiar with the basic concepts and terms used in discrete manufacturing. You are interested in predicting the performance of your factory or evaluating the impact of some proposed changes. A familiarity with computers and the Microsoft[®] Windows[®] operating system is assumed. A familiarity with the concepts and terms used in simulation is also helpful.

Installation and startup

Before installing the software, we recommend that you review the product information contained in the *RSBizWare Administrator's Guide*. Then follow the step-by-step procedures outlined in the guide (or referenced on the quick-start checklist card enclosed in your package) to attain a successful installation and configuration of your software.

The *Administrator's Guide* also includes valuable information on hardware/software requirements; reinstalling the software; activations, privileges, and permissions; and installing and creating SQL Server databases.

Note: It is also important to review the Release Notes file located on the installation CD-ROM. This file lists the hardware and software that is necessary to use the RSBizWare software effectively, known issues and anomalies, and new features of the current release of the software.

Where can I go for help?

Our commitment to your success starts with the suite of learning aids and assistance we provide with FactoryTalk Scheduler. Whether you're new to finite-capacity scheduling or a seasoned veteran putting a new tool to use, you'll quickly feel at home with FactoryTalk Scheduler.

Reference the user's guides

Printed copies of the *RSBizWare Administrator's Guide* and the *FactoryTalk Scheduler User's Guide* are distributed in the box with the software and an electronic copy of each guide is available from the RSBizWare software installation CD-ROM or from the

technical support group. Additionally, electronic copies of the *FactoryTalk Scheduler Customization Guide* and the *FactoryTalk Scheduler FDM Configuration Guide* are provided on the software CD-ROM.

RSBIZWARE ADMINISTRATOR'S GUIDE

The *RSBizWare Administrator's Guide* is designed to help the administrator install and configure the software and to understand the components that make up the RSBizWare suite of products. The first chapter of the guide provides an overview of the software components that make up the RSBizWare suite and describes the architecture on which they are built. The remaining chapters describe the installation steps and the options you have when deploying the RSBizWare software in your enterprise.

FACTORYTALK SCHEDULER USER'S GUIDE

The documentation set also includes the *FactoryTalk Scheduler User's Guide* product manual, which cover the product basics in easy, "click-by-click" tutorials that define and demonstrate many of FactoryTalk Scheduler's features.

DOCUMENT CONVENTIONS

Throughout the guides, a number of style conventions are used to help identify material. New terms and concepts may be emphasized by use of italics or bold; file menu paths are in bold with a (>) separating the entries (e.g., go to File > New); text you are asked to type is shown in Courier Bold (e.g., in this field, type Work Week), and dialog button names are shown in bold (e.g., click OK).

Get help online

Online help is always at your fingertips! FactoryTalk Scheduler help incorporates general overview information, comprehensive step-by-step procedures, and context-sensitive control definitions (e.g., text boxes, drop-down lists, and option buttons) for working with all of the software features. To view online help while running the FactoryTalk Scheduler software:

- select Help > FactoryTalk Scheduler Help from the FactoryTalk Scheduler main menu for a full help listing,
- click the Help button on any FactoryTalk Scheduler dialog to open help for that dialog only,
- click the Help button on the File toolbar, then click anywhere on the user interface to receive help on that element, or
- click the What's This? icon in the upper-right corner of any FactoryTalk Scheduler dialog, then on any control to receive a definition of that control.

Get phone support

The Rockwell Automation support team of outstanding professionals provides top-notch technical support—monitoring and tracking your experience with our products to pave the road to your success in understanding and improving your factory performance.

Rockwell Automation provides full support for the entire RSBizWare suite of products, which include FactoryTalk Historian Classic, FactoryTalk Metrics, FactoryTalk Transaction Manager, FactoryTalk Scheduler. Questions concerning installation and the use of the software are handled by the Rockwell Automation Customer Support Center, staffed from 8 AM to 5 PM (in your time zone) Monday through Friday—except U.S. holidays—for calls originating within the U.S. and Canada.

To reach the Customer Support Center, call 1.440.646.3434 and follow the prompts. For calls originating outside the U.S./Canada, locate the number in your country by linking to <u>support.rockwellautomation.com</u> and selecting the <u>Phone/On-site</u> link. A list will be presented from which you can locate the number to call inyour country.

WHEN YOU CALL

When you call, you should be at your computer and prepared to give the following information:

- the product serial number and version number, which can be found in the client software by selecting Help > About,
- the type of hardware you are using,
- the exact wording of any errors or messages that appeared on your screen
- a description of what happened and what you were doing when the problem occurred, and
- a description of how you attempted to solve the problem.

Get Web support

In addition to phone support, the Rockwell Automation Customer Support Center offers extensive online knowledgebases of tech notes and frequently asked questions for support of non-urgent issues. These databases are updated daily by our support specialists.

To receive regular e-mail messages with links to the latest tech notes, software updates, and firmware updates for the products that are of interest to you or to submit an online support request, go to <u>support.rockwellautomation.com</u> and select the <u>Online</u> link.

Get on-site support

For on-site support, Rockwell Automation field support engineers are located around the globe to provide assistance with special projects, unexpected problems, or emergency situations. Field support engineers are available for dispatch 24x7x365 and can arrive at many locations the same day.

To learn more about this and other support services, visit the Rockwell Automation Web site at <u>www.rockwellautomation.com/support</u>.

Get consulting services

Rockwell Automation provides expert consulting and turnkey implementation of the RSBizWare suite. Please call your local Rockwell Automation representative for more information.

Contact us

We strive to help all of our customers become successful in their manufacturing improvement efforts. Toward this objective, we invite you to contact your local representative or Rockwell Automation at any time that we may be of service to you. Numbers for the support group are listed on the copyright page of this book.

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Introducing BizBikes



This chapter describes a sample company, BizBikes Inc., whose manufacturing system will be referred to in upcoming tutorial chapters. BizBikes manufactures bicycles that are sold to independent bicycle shops. The BizBikes factory was selected because it contains representative key features of the RSBizWare

product suite, including FactoryTalk Historian Classic, FactoryTalk Metrics, FactoryTalk Transaction Manager, and FactoryTalk Scheduler.

Roll up your sleeves and take a walk through the factory with us as we study the system and how it operates. Let's start by learning about the business environment, and then we'll spend some time getting familiar with the manufacturing process.

How BizBikes are manufactured

BizBikes produces bicycles in two different styles (Standard (SSD) and High Performance (SHP)) and in two different colors (red and blue). With the exception of the frames, the two models and color variations use all the same manufactured and purchased components.

The BizBikes manufacturing facility can be broken into these logical areas:

Machining and Fabrication Paint Shop Subassembly Final Assembly and Ship

There are also two Original Equipment Manufacturers (OEMs) resident on the BizBikes campus who manufacture sprockets and seats. These finished goods are supplied to BizBikes for final assembly.

In the machining and fabrication area, BizBikes manufactures the frames, seat posts, handlebars, and neck post. These component parts are produced by processing raw material through a series of work cells that cut, bend, machine, weld, and finish components. After parts complete the machining and fabrication steps, the frames are batched and sent to the paint shop, and the other component parts go into inventory where they can be pulled from stock as needed to meet demand in the assembly area. In the next stage, each bicycle is assembled based on customer order requirements with parts and subassemblies (both manufactured and purchased) supplied from inventory. In the last step, the bicycle (with its wheels and handlebar removed) is packed in a corrugated box and shipped.

BizBikes business problems

BizBikes has been losing market share to competitors due to both pricing pressure and problems with on-time delivery. Business conditions have forced a transition from make-to-stock to make-to-order, and the bicycle shops that receive the goods are complaining about frequent late deliveries. Thin margins and decrease in market share have produced losses for the past two quarters. A task force was set up to analyze the problem and to recommend a solution that will improve key performance indicators, such as lowering our manufacturing costs, shortening our production time, and improving our on-time delivery.

Challenges:

- Must quote accurately and meet delivery dates
- Compete with competitor information and alternative suppliers that are readily accessible via Internet
- Must provide accurate, up-to-the-minute information on order and shop-floor resource status to the rest of the organization
- Critical to monitor, analyze, and improve the manufacturing processes through up-todate software and information technology
- Must drive down the cost of manufacturing while maximizing resource utilization and machine uptime

How FactoryTalk Scheduler will help solve the BizBikes production problems

Through FactoryTalk Scheduler's finite-capacity scheduling strategies and simulationbased scheduling, the management and shop-floor teams at BizBikes now perform "whatif" analyses of the production sequences in a fraction of the time they previously spent. Implementing FactoryTalk Scheduler in their "toolbox" allows for the generation of realistic production scenarios that show the effects of schedule changes, maintenance downtimes, tooling, shifts, and other key factors that determine the factory capacity and delivery times. In minutes, FactoryTalk Scheduler generates production schedules that used to take hours, so the teams spend their time managing the bicycle orders, not calculating capacity.

And with FactoryTalk Scheduler's accurate representation of the system and its operation, the teams at BizBikes can constantly monitor the factory's performance and make timely decisions to increase throughput and cut the WIP, overtime, and on-hand inventory.

In the next chapter, we'll take a look at the impact of FactoryTalk Scheduler in the BizBikes factory by first examining their manufacturing system.

2 • THE BIZBIKES FACTORY

Learn more about RSBizWare

See how RSBizWare solutions impact the BizBikes manufacturing system by visiting <u>www.software.rockwell.com/bizbikes/</u>.

For more comprehensive product information and to view application profiles of actual companies' successes, be sure to visit the RSBizWare Web site at www.software.rockwell.com/rsbizware/.

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The BizBikes manufacturing system

To begin our assessment of the BizBikes factory, we'll first examine their manufacturing system and learn about the factory resources and processes. We will then use this model to examine possible scenarios for improving our performance.

Bill of materials

The bill of materials for BizBikes contains three levels, as shown below, for a generic end item. There are actually four end items (or BizBikes), 15 unique manufactured items, and five purchased parts. The shaded items in the bill of materials represent manufactured components. This generic bill of materials also includes information on manufacturing lead times, number required per subassembly, and lot size information.



KEY: (Lead Time, Quantity, Lot Size)

The Manufacturing Resource Planning system

BizBikes employs a Manufacturing Resource Planning (MRP) system that performs master planning and scheduling of weekly production. The MRP system consolidates orders from multiple customers and plans the purchase and manufacturing of the associated components. The MRP produces a set of *manufacturing orders* that are released to the factory floor. These manufacturing orders are for both component parts

(frames, handlebars, etc.) as well as final assemblies. The components are produced tostock and are consumed during the subassembly and the final assembly and pack of a bicycle. The MRP also nets together purchased components across multiple customer orders. The MRP netting operation generates purchase requests for component parts (brakes, wheels, seats, etc.) based on economic order quantities and lead times. The MRP system also plans out and issues purchase requests for materials consumed in manufacturing component parts. The purchase requests for both component parts and raw materials are issued to suppliers who then ship these components to our factory. In the final assembly, we combine the manufactured and purchased components into a bicycle, which is then packed and shipped to the customer.

The following table shows production requirements for a typical ten-day period. These manufacturing orders have been downloaded from the MRP and include orders for SHP and SSD bicycles in both red and blue, along with MRP-generated orders for components required during assembly. The 70 manufacturing orders include 33 orders for finished BizBikes, 25 subassemblies, and 12 component parts.

Order #	Product Name	Order Quantity	Release Date	Due Date
SHP Red 1	SHP Red Bicycle	15	2/11/03 11 РМ	2/12/03 11 РМ
SHP Red 2	SHP Red Bicycle	9	2/12/03 11 РМ	2/13/03 11 РМ
SHP Red 3	SHP Red Bicycle	8	2/13/03 11 РМ	2/14/03 11 РМ
SHP Red 4	SHP Red Bicycle	12	2/14/03 11 РМ	2/17/03 11 РМ
SHP Red 5	SHP Red Bicycle	17	2/17/03 11 РМ	2/18/03 11 РМ
SHP Red 6	SHP Red Bicycle	20	2/18/03 11 РМ	2/19/03 11 РМ
SHP Red 7	SHP Red Bicycle	9	2/19/03 11 РМ	2/20/03 11 РМ
SHP Red 8	SHP Red Bicycle	7	2/20/03 11 РМ	2/21/03 11 РМ
SHP Blue 1	SHP Blue Bicycle	11	2/10/03 11 РМ	2/11/03 11 РМ
SHP Blue 2	SHP Blue Bicycle	6	2/11/03 11 РМ	2/12/03 11 РМ
SHP Blue 3	SHP Blue Bicycle	4	2/12/03 11 РМ	2/13/03 11 РМ
SHP Blue 4	SHP Blue Bicycle	14	2/13/03 11 РМ	2/14/03 11 РМ
SHP Blue 5	SHP Blue Bicycle	11	2/14/03 11 РМ	2/17/03 11 РМ
SHP Blue 6	SHP Blue Bicycle	16	2/17/03 11 PM	2/18/03 11 PM
SHP Blue 7	SHP Blue Bicycle	8	2/18/03 11 РМ	2/19/03 11 РМ
SHP Blue 8	SHP Blue Bicycle	6	2/19/03 11 РМ	2/20/03 11 РМ
SHP Blue 9	SHP Blue Bicycle	15	2/20/03 11 РМ	2/21/03 11 РМ
SSD Red 1	SSD Red Bicycle	11	2/10/03 11 РМ	2/11/03 11 РМ
SSD Red 2	SSD Red Bicycle	9	2/11/03 11 РМ	2/12/03 11 РМ
SSD Red 3	SSD Red Bicycle	8	2/12/03 11 РМ	2/13/03 11 РМ
SSD Red 4	SSD Red Bicycle	14	2/13/03 11 РМ	2/14/03 11 РМ
SSD Red 5	SSD Red Bicycle	12	2/17/03 11 РМ	2/18/03 11 РМ
SSD Red 6	SSD Red Bicycle	7	2/18/03 11 РМ	2/19/03 11 РМ
SSD Red 7	SSD Red Bicycle	6	2/19/03 11 РМ	2/20/03 11 РМ
SSD Red 8	SSD Red Bicycle	12	2/20/03 11 РМ	2/21/03 11 РМ
SSD Blue 1	SSD Blue Bicycle	5	2/11/03 11 РМ	2/12/03 11 РМ
SSD Blue 2	SSD Blue Bicycle	16	2/12/03 11 РМ	2/13/03 11 РМ
SSD Blue 3	SSD Blue Bicycle	9	2/13/03 11 РМ	2/14/03 11 РМ
SSD Blue 4	SSD Blue Bicycle	12	2/14/03 11 РМ	2/17/03 11 РМ
SSD Blue 5	SSD Blue Bicycle	8	2/17/03 11 РМ	2/18/03 11 РМ
SSD Blue 6	SSD Blue Bicycle	13	2/18/03 11 PM	2/19/03 11 PM
SSD Blue 7	SSD Blue Bicycle	18	2/19/03 11 РМ	2/20/03 11 РМ
SSD Blue 8	SSD Blue Bicycle	15	2/20/03 11 РМ	2/21/03 11 РМ
SHP Red Finished Frame 1	SHP Red Finished Frame	24	2/10/03 11 РМ	2/11/03 11 РМ
SHP Red Finished Frame 2	SHP Red Finished Frame	24	2/13/03 11 РМ	2/14/03 11 РМ
SHP Red Finished Frame 3	SHP Red Finished Frame	24	2/14/03 11 РМ	2/17/03 11 РМ
SHP Red Finished Frame 4	SHP Red Finished Frame	24	2/17/03 11 РМ	2/18/03 11 РМ
SHP Blue Finished Frame 1	SHP Blue Finished Frame	24	2/10/03 11 РМ	2/11/03 11 РМ
SHP Blue Finished Frame 2	SHP Blue Finished Frame	24	2/13/03 11 PM	2/14/03 11 PM
SHP Blue Finished Frame 3	SHP Blue Finished Frame	24	2/17/03 11 РМ	2/18/03 11 РМ
SHP Blue Finished Frame 4	SHP Blue Finished Frame	24	2/19/03 11 РМ	2/20/03 11 РМ
SSD Red Finished Frame 1	SSD Red Finished Frame	24	2/10/03 11 РМ	2/11/03 11 РМ

Order #	Product Name	Order Quantity	Release Date	Due Date
SSD Red Finished Frame 2	SSD Red Finished Frame	24	2/12/03 11 РМ	2/13/03 11 РМ
SSD Red Finished Frame 3	SSD Red Finished Frame	24	2/18/03 11 РМ	2/19/03 11 РМ
SSD Blue Finished Frame 1	SSD Red Finished Frame	24	2/11/03 11 РМ	2/12/03 11 РМ
SSD Blue Finished Frame 2	SSD Blue Finished Frame	24	2/13/03 11 РМ	2/14/03 11 PM
SSD Blue Finished Frame 3	SSD Blue Finished Frame	24	2/17/03 11 РМ	2/18/03 11 PM
SSD Blue Finished Frame 4	SSD Blue Finished Frame	24	2/18/03 11 РМ	2/18/03 11 РМ
Handlebar Assembly 1	Handlebar Assembly	75	2/10/03 11 РМ	2/11/03 11 РМ
Handlebar Assembly 2	Handlebar Assembly	75	2/12/03 11 РМ	2/13/03 11 РМ
Handlebar Assembly 3	Handlebar Assembly	75	2/14/03 11 РМ	2/17/03 11 РМ
Handlebar Assembly 4	Handlebar Assembly	75	2/17/03 11 РМ	2/18/03 11 РМ
Handlebar Assembly 5	Handlebar Assembly	75	2/19/03 11 РМ	2/20/03 11 PM
Seat Assembly 1	Seat Assembly	75	2/10/03 11 РМ	2/11/03 11 РМ
Seat Assembly 2	Seat Assembly	75	2/12/03 11 РМ	2/13/03 11 РМ
Seat Assembly 3	Seat Assembly	75	2/14/03 11 РМ	2/17/03 11 РМ
Seat Assembly 4	Seat Assembly	75	2/17/03 11 РМ	2/18/03 11 РМ
Seat Assembly 5	Seat Assembly	75	2/19/03 11 РМ	2/20/03 11 РМ
Handlebar 1	Handlebar	100	2/11/03 11 РМ	2/14/03 11 РМ
Handlebar 2	Handlebar	100	2/12/03 11 РМ	2/17/03 11 РМ
Handlebar 3	Handlebar	100	2/14/03 11 РМ	2/19/03 11 РМ
Neck Post 1	Neck Post	60	2/11/03 11 РМ	2/14/03 11 PM
Neck Post 2	Neck Post	120	2/12/03 11 РМ	2/17/03 11 РМ
Neck Post 3	Neck Post	60	2/14/03 11 РМ	2/19/03 11 PM
SHP Frame 1	SHP Frame	50	2/10/03 11 РМ	2/14/03 11 РМ
SHP Frame 2	SHP Frame	50	2/11/03 11 РМ	2/17/03 11 РМ
SSD Frame 1	SSD Frame	50	2/11/03 11 РМ	2/17/03 11 РМ
SSD Frame 2	SSD Frame	50	2/12/03 11 РМ	2/18/03 11 РМ
Seat Post 1	Seat Post	100	2/12/03 11 РМ	2/17/03 11 РМ
Seat Post 2	Seat Post	100	2/14/03 11 РМ	2/19/03 11 РМ

The BizBikes manufacturing resources

The BizBikes manufacturing plant contains seven work cells (Cut, Machine, Bend, Weld, Finish, two Subassembly areas, and two Assembly and Pack areas), and a three-person labor pool per shift (labor required by Subassembly and Assembly and Pack). All work cells and labor are available for two eight-hour shifts, five days a week (a 2/5 composite shift pattern). The first shift starts at 7 AM and ends at 3 PM. The second shift starts at 3 PM and ends at 11 PM. There are no scheduled breaks in either shift. The key differences for the processes at the various work cells are summarized below. Keep in mind that all setup and process durations are expressed in hours.

ASSEMBLY AND PACK

These work cells are used to assemble and pack the finished BizBikes. The setup and process (per item) durations are part dependent. Each assembly operation requires two labor units from the labor pool for its entire duration.

SUBASSEMBLY

These work cells are used to assemble component parts (manufactured and purchased) into subassemblies that are placed in stock for future required orders. The setup and process (per item) durations are part dependent. Each subassembly operation requires one labor unit from the labor pool for its entire duration.

FINISH AND CUT

These work cells are utilized for operations necessary to produce the component parts required for the subassemblies. The setup and process (per item) durations are part dependent. These work cells are manned by a dedicated operation and do not require labor from the labor pool.

MACHINE AND BEND

These work cells are utilized for operations necessary to produce the component parts required for the subassemblies. The process (per item) durations are part dependent. These work cells are manned by a dedicated operation and do not require labor from the labor pool. The setup durations for these work cells are sequence dependent and defined in matrix MM for the Machine work cell and matrix BM for the Bend work cell. These two matrices are shown below.

	SSD Frame	SHP Frame	Handlebar	Neck Post
SSD Frame	0.00	0.12	0.53	0.58
SHP Frame	0.14	0.00	0.55	0.62
Handlebar	0.64	0.66	0.00	0.26
Neck Post	0.57	0.61	0.33	0.00

Machine Setup Matrix: MM

This matrix shows the setup time for an operation based on the previous production lot that was processed at this work cell. For example, if the last production lot was *Handlebar*, then the setup time to produce a Neck Post is .26 hours.

Bend	Setup	Matrix:	BM
D0110	Colup	in a ci i i i i i i i i i i i i i i i i i	

	SSD Frame	SHP Frame	Handlebar	Neck Post
SSD Frame	0.00	0.35	0.84	0.32
SHP Frame	0.42	0.00	0.84	0.32
Handlebar	0.93	0.97	0.00	0.28
Neck Post	0.75	0.78	0.39	0.00

WELD

This work cell is also utilized for operations necessary to produce the component parts required for the subassemblies. The process (per item) durations are part dependent. These work cells are manned by a dedicated operation and do not require labor from the labor pool. The setup duration for this work cell depends upon the frame type; i.e., we have a different setup time for an *SHP Frame* and an *SSD Frame*. The setup time required to change to an *SHP Frame* is 0.72 hours, and the time required to change to an *SSD Frame* is 0.70 hours.

Process plans

There are eight different manufacturing order types, each with a different process plan or routing.

FINAL ASSEMBLY AND PACK

The process plans for assembly and packing of the SHP Red, SHP Blue, SSD Red, and SSD Blue bicycles contain a single assembly operation. In this operation, a bicycle is assembled from its components and subassemblies and then packaged for shipping. The process plan for *SHP Red Bicycle* final assembly is summarized below.

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble and Pack	Assembly and Pack	0.37	0.43	Labor (2)	Components required

SHP Red Bicycle Plan

The components required before this operation can be started are the manufactured parts SHP Red Finished Frame, Handlebar Assembly, and Seat Assembly and the purchased parts Pedal and Chain Assembly, Wheels, Derailleur Assembly, and Brakes.

FINISHED FRAME

The process plans for a finished frame (SHP Red, SHP Blue, SSD Red, and SSD Blue) contain two operations. The frame parts are first finished (red or blue) and then the parts are subassembled. The finished frame is then placed in inventory where it is available for demand from a final assembly order. The process plan for *SHP Red Finished Frame* is summarized below.

SHP Red Finished Frame Plan

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Finish SHP Red Frame	Finish	0.11	0.155		SHP Frame required
20	Subassemble SHP Frame	Subassembly	0.19	0.083	Labor (1)	Place in inventory



FRAME

The process plans for a frame (SHP or SSD) contain four operations: cut, bend, machine, and weld. The frame is then placed in inventory to be used by orders for finished frames. The raw materials required at both the cut and weld operations have not been included in the process plan as the material-planning replenishment process at the MRP level assures that adequate materials will be available. The process plan for *SHP Frame* is summarized next.

SHP Frame Plan

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Cut SHP Frame Tubing	Cut	0.36	0.120		
20	Bend SHP Frame Tubing	Bend	BM	0.154		
30	Machine SHP Frame Tubing	Machine	MM	0.211		
40	Weld SHP Frame	Weld	WD	0.234		Place in inventory



HANDLEBAR ASSEMBLY

The process plans for the handlebar assembly contain a single subassembly operation. In this operation, the previously manufactured handlebars and neck posts are assembled. The subassembly is then placed in inventory where it is available for demand from a final assembly order. The component parts required for this subassembly are a handlebar and neck post for each subassembly to be produced. The process plan for *Handlebar Assembly* is summarized below.

Handlebar Assembly Plan

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble Handlebar	Subassembly	0.21	0.072	Labor (1)	Handlebar and Neck Post required; Place in inventory



HANDLEBAR

The process plans for a handlebar contain three operations: cut, bend, and finish. The completed handle is then placed in inventory to be used by orders for handlebar assemblies. The raw materials required at the cut operation have not been included in the process plan as the material-planning replenishment process at the MRP level assures that

adequate materials will be available. The process plan for *Handlebar* is summarized below.

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Cut Handlebar Tubing	Cut	0.16	0.055		
20	Bend Handlebar Tubing	Bend	BM	0.043		
30	Finish Handlebar	Finish	0.14	0.088		Place in inventory

Handlebar Plan



NECK POST

The process plans for a handlebar contain four operations: cut, machine, bend, and finish. The completed neck post is then placed in inventory to be used by orders for handlebar assemblies. The raw materials required at the cut operation have not been included in the process plan as the material-planning replenishment process at the MRP level assures that adequate materials will be available. The process plan for *Neck Post* is summarized below.

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Cut Neck Post	Cut	0.21	0.065		
20	Machine Neck Post	Machine	MM	0.120		
30	Bend Neck Post	Bend	BM	0.072		
40	Finish Neck Post	Finish	0.14	0.074		Place in inventory

Neck Post Plan



SEAT ASSEMBLY

The process plans for the seat assembly contain a single subassembly operation. In this operation, the previously manufactured seat post and purchased seat are assembled. The subassembly is then placed in inventory where it is available for demand from a final assembly order. The component parts required for this subassembly are a seat post and seat for each subassembly to be produced. The process plan for *Seat Assembly* is summarized below.

Seat Assembly Plan

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble Seat and Post	Subassembly	0.20	0.084	Labor (1)	Seat and Seat Post required; Place in inventory



SEAT POST

The process plans for a seat post contain two operations: cut and machine. The completed seat post is then placed in inventory to be used by orders for seat assemblies. The raw materials required at the cut operation have not been included in the process plan as the material-planning replenishment process at the MRP level assures that adequate materials will be available. The process plan for *Seat Post* is summarized below.

Seat Post Plan

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Material Consumed	Material Produced
10	Cut Seat Post	Cut	0.17	0.068			
20	Machine Seat Post	Machine	MM	0.130			Seat Post



Purchased components

In addition to the manufactured components, we also have purchased components that are used in the assembly operations. Purchase orders for these components are automatically generated by the MRP (based on the economic lot size and lead times) to meet the manufacturing demands. The following table summarizes the purchased components for this same sample ten-day production period.

Material Name	Quantity	Date
Pedal and Chain Assembly	60	6/10/02 6:00 PM
Pedal and Chain Assembly	60	6/13/02 6:00 PM
Pedal and Chain Assembly	60	6/19/02 6:00 PM
Brakes	75	6/12/02 6:00 PM
Brakes	75	6/18/02 6:00 PM
Wheels	48	6/12/02 6:00 PM
Wheels	48	6/17/02 6:00 PM
Wheels	48	6/19/02 6:00 PM
Derailleur Assembly	60	6/12/02 6:00 PM
Derailleur Assembly	60	6/17/02 6:00 PM
Derailleur Assembly	60	6/20/02 6:00 PM
Seat	100	6/10/02 6:00 PM

Inventories

We have a starting inventory level for both the manufactured and the purchased material. The following table summarizes the starting inventory of these items.

Material	Туре	Initial Quantity
SHP Red Bicycle	Make	0
SHP Blue Bicycle	Make	0
SSD Red Bicycle	Make	0
SSD Blue Bicycle	Make	0
SHP Red Finished Frame	Make	8
SHP Blue Finished Frame	Make	16
SSD Red Finished Frame	Make	17
SSD Blue Finished Frame	Make	6
Handlebar Assembly	Make	27
Seat Assembly	Make	36
SHP Frame	Make	97
SSD Frame	Make	54
Seat Post	Make	127
Handlebar	Make	155
Neck Post	Make	118
Pedal and Chain Assembly	Buy	15
Brakes	Buy	50
Wheels	Buy	54
Derailleur Assembly	Buy	54
Seat	Buy	54

Previously scheduled orders

Finally, we have previously scheduled orders planned for completion. These orders are shown below.

Material Name	Quantity	Date
Seat Post	100	2/12/03 6:00 PM
Neck Post	60	2/12/03 6:00 PM
SSD Frame	50	2/12/03 6:00 PM

Summary

Now that we have described the BizBikes manufacturing process, we'll use the information in the tutorial to illustrate the features of FactoryTalk Scheduler in Chapter 4.



FactoryTalk Scheduler provides a wide range of features for modeling constrained scheduling systems. There are four basic categories of modeling constraints available—**resource**, **sequencing**, **material**, **fixture**, and **operation**. We will discuss the major features for each of them and use the BizBikes tutorial from Chapter 3 to demonstrate examples.

Resource constraints

FactoryTalk Scheduler provides full support for the scheduling of constrained resources with four distinct resource types:

- Singular
- Infinite
- Simultaneous
- Adjustable Pooled

The resource types differ in the functionality that they provide in modeling a wide variety of production environments.

The **Singular** resource is the most commonly used type. It represents a single machine, person, device, jig, fixture, or any resource that is constrained and has a capacity of one.

Tutorial: For our tutorial system, we will model the resources as Singular in work cells Bend, Cut, Finish, Machine, Weld, Subassembly, and Assembly and Pack, as each resource can only perform one operation at a time.

The **Infinite** resource type provides the ability to represent resources that have an unlimited capacity. The most common example is a subcontractor or a drying area. Although a subcontractor has a theoretical infinite capacity, it still requires time to complete the task and may work only a single shift.

Tutorial: We will not use this resource type in our tutorial system.

The **Simultaneous** resource type represents resources that may have the ability to handle multiple activities. It is further restricted in that if a Simultaneous resource processes multiple activities at the same time, all the activities must be *synchronized*. This means that they must all start and end at the same time. The significance of this feature is best described by considering a kiln with a capacity measured in cubic feet. The kiln can be used to process any number of parts, as long as the volume of the parts does not exceed the kiln capacity. The synchronized restriction means that once you load and start the kiln, you must finish that process before it can be used to process any additional parts. You can

also restrict what operations can be processed at the same time by requiring that certain operation attributes match before they can be processed together.

Tutorial: We will not use this resource type in our tutorial system.

The **Adjustable Pooled** resource type is most often used to represent pools of like resources, any one of which fulfills the requirement of the task or operation being performed. Typical examples are labor pools, totes, fixtures, or space. The number of units of an Adjustable Pooled resource can vary during the operation span. We will elaborate on this difference shortly.

Tutorial: The labor pool in our tutorial will be modeled as an Adjustable Pooled resource.

Primary and additional resources

Each operation to be scheduled must have a single primary resource for the entire duration of the operation. Operation durations can be separated into three phases. Normally, these are referred to as **setup**, **process**, and **teardown**. Additional resources can be specified for the entire operation or for an individual phase of the operation. There is no limit on the number of additional resources that an operation may require. However, as the number of additional resources increases, the scheduling problem becomes more complex. This will result in more time being required to develop a solution.

Shift patterns and efficiency

You can associate shift patterns, preventive maintenance, downtimes, etc., with any resource. In addition to shift patterns, you can also associate an efficiency, expressed as a fraction, with Singular, Infinite, and Simultaneous resources. Typically, this efficiency would be defaulted to 1.0. By changing the efficiency, you can speed up or slow down those operations that use the resource.

Resource sets

FactoryTalk Scheduler schedules to either a **resource** or a **resource set**. A resource set contains one or more resources. When a resource set contains multiple resources, the resources are typically of the same type, although it is not required. Likewise, it is not required that the names used for resource sets differ from those of resources, but this is the most common naming convention. Furthermore, a resource may be included in more than one set.

Tutorial: In our tutorial system, we will have six resources: Bender, Cutter, Finisher, Machiner, Welder, and Labor. You might note that although Labor is a single resource, it will have a capacity greater than one. We also have two resource sets, Subassembly Areas and Assembly and Pack Areas, each with two resources. The two subassembly resources are called Subassembly Area 1 and Subassembly Area 2. The two assembly resources are called Assembly and Pack Area 1 and Assembly and Pack Area 2. We will associate a 1/5-shift pattern with all the resources.

The combination of the availability of required resources and resource efficiencies determine both where and how FactoryTalk Scheduler places an operation on the planning board during the scheduling process. A resource becomes unavailable for use by an operation in a given time period if it is currently being used by another operation or if it is in an off-shift state.

Simultaneous, Singular, and Infinite resource spanning

Consider an operation that requires two hours of processing time on a Singular resource. Assume that the resource is continuously on-shift starting at 7 AM until 3 PM and is off-shift the rest of the day. Also assume that there are no other operations currently using the resource. If the operation were unable to start until 12:30 PM, FactoryTalk Scheduler would schedule the operation from 12:30 PM to 2:30 PM, taking a continuous two-hour span of time. However, if the operation were unable to start until 2 PM, FactoryTalk Scheduler would schedule the operation to start at 2 PM on the current day, where it would process for one hour. It would then resume processing the next day at 7 AM to complete the two-hour operation by 8 AM.

When an operation crosses a time where a resource is in an off-shift state or at a reduced efficiency, it is called spanning. If an operation requires several secondary resources with different shift patterns, the spanning can become quite complicated. However, as long as all the required resources are Simultaneous, Singular, or Infinite types, no other operations can use these resources during the span time of the scheduled operation. Note that if one of these resources is a Simultaneous type, other operations may use any excess capacity.

Adjustable Pooled resource spanning

Adjustable Pooled resources differ not only in the manner in which resource spanning is allowed, but also because you can elect to not allow certain types of spanning for individual Adjustable Pooled resources. We'll first discuss the default spanning mode.

The spanning behavior of Adjustable Pooled resources is best illustrated with an example.

The diagram below shows the availability profile of a labor resource. This profile represents a 2/5 shift pattern with three workers available during the first shift (7 AM to 3 PM), two available during the second shift (3 PM to 11 PM), and none available during the third shift. Note that the diagram shows that there is currently an operation, represented by the white area, which has been allocated one labor unit from 10 AM to 9 PM on Day 1.

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Let us assume that FactoryTalk Scheduler is going to schedule an operation that requires a primary resource that is available 24 hours a day and currently is not being used during Days 1 or 2. This operation also requires two units of labor during its six-hour operation time. If the operation were available to start on or before 9 AM of Day 1, it could be scheduled during the first day. For example, if the operation could start at 8 AM, it would be scheduled from 8 AM to 2 PM, as shown below.



Adjustable Pooled resources not only allow spanning, but they also allow the number of labor units to vary, which will pace the operation. Thus, Adjustable Pooled resources are often used to model resources where the pace or efficiency of the operation is based on the number of workers currently available. Again, this is best illustrated using an example.

Let's assume that we want to schedule the same six-hour operation as before. If the operation could not start until 1 PM on Day 1, it would be scheduled from 1 PM to 10 PM,



as shown below. Although this operation time is six hours, this particular process spans a nine-hour period because it's paced by the labor availability.

Between 1 PM and 3 PM, there are two units of the resource available. Thus, the operation is assumed to be at 100% efficiency during that time. However, between 3 PM and 9 PM, there is only one unit of labor available. The operation will continue during this six-hour period at 50% efficiency, which accounts for an additional three hours of operation time. During the last hour of the operation, the efficiency returns to 100% because two labor units are available.

The spanned operation time can also include periods when there are no units available, resulting in a zero efficiency during that time. *The total number of units requested must be available when the operation starts*. For example, if the operation could not begin until 4 PM of Day 1, the start of the operation would have to be delayed until 9 PM on Day 1 and would finish at 11 AM on Day 2, as shown below.



Although the operation could start at 4 PM, there is only one unit of labor available from 3 PM to 9 PM, so the scheduled start of the operation would be at 9 PM when there are two units available. From 9 PM to 11 PM, the operation is at 100% efficiency—accounting for the first two hours of the operation. From 11 PM of Day 1 to 7 AM of Day 2, there are no units available, resulting in zero efficiency. The last four hours of the operation occur at 100% efficiency with two units available from 7 AM to 11 AM of Day 2.

You also have the option of specifying a minimum number of units that must be available for the operation to continue (the default is zero). This minimum value must be fewer than or equal to the total number of units requested. Let's consider the same six-hour operation with a minimum equal to the total number, or two units. If the operation cannot start until 1 PM on Day 1, it would be scheduled from 1 PM to 9 AM of Day 2, as shown below. This particular process spans a 12-hour period because it requires two units during the entire operation. Thus, it spans the time from 3 PM to 9 PM where there is only one unit available.



Consider an example where the total number of units required is five and the minimum number of units is three. The operation could not start until there were five units available, and it would continue as long as there were three or more units available, although it would occur at a lower efficiency if there were only three or four units available during that time. If the operation is started and there is a point where there are fewer than three units available, the operation will span (at zero efficiency) this time until there are at least three units available, at which time it would resume.

As mentioned earlier, you can also elect to not allow certain types of spanning for specific Adjustable Pooled resources. If you make this election, it will allow spanning to occur during off-shift states, but it will not allow spanning where the resource is unavailable because it is being used by another operation.

Sequencing constraints

Sequencing constraints are normally a part of the product or job routing and determine the sequence in which operations can be performed. Many systems have simple or straight routings where the sequence is simply determined by the order in which the operations are listed. The first operation must be completed before the second one can start, the second completed before the third can start, and so on. Other systems allow parallel or concurrent operations in their routings. These types of systems often include assembly or disassembly operations. The most difficult sequencing constraints are found in systems where routings are represented as networks. These types of routings are most frequently found in maintenance operations.

FactoryTalk Scheduler provides complete support for all types and combinations of sequencing constraints. There are two different ways to describe sequencing constraints: using an operation sequence numbering scheme or using an immediate successor operation(s) scheme. The two methods cannot be used together in the same application. All sequencing constraints for a given application must be described using the same scheme.

The operation sequence numbering scheme

The operation sequence numbering scheme has the following format:

XX.YY.YY.YY...

where:

XX is the standard integer operation sequence number and will be referred to as the root operation number

YY is the integer suffix that can be appended to the basic number, separated by the decimal character "."

You can append as many suffixes as needed to represent your routings accurately. The rules used by FactoryTalk Scheduler to determine the sequence of operations are:

- 1. If the operation sequence number consists of only a root operation number (only **XX**), then all operations with lower root numbers (ignoring all suffixes) must precede that operation. Conversely, all operations with higher root numbers (ignoring all suffixes) must succeed that operation. *Note that it is possible to have one or more operations with the same root number, with or without suffixes.*
- 2. If the operation sequence number consists of a root operation number and one or more suffixes, then:
 - all operations with lower root numbers and the same exact suffixes must precede that operation,

- all operations with lower root numbers and a fewer number of suffixes must precede that operation, as long as the remaining suffixes match,
- all operations with lower root numbers and the same suffixes, but with additional appended suffixes must precede that operation, and
- the converse defines the operations that succeed that operation.

The immediate successor operation(s) scheme

The operation number in the immediate successor operation scheme does not include any sequence information. The sequence of operations is determined by specifying an additional operation field, called the immediate successor operation attribute. The rules for this scheme are:

- each operation in a routing must have a unique job step number,
- the operation numbers cannot include suffixes,
- the immediate successor operation attribute field defines the immediate successor operation job step number,
- if an operation has no successor, the immediate successor operation attribute field is left blank, and
- if an operation has multiple successors, the job step numbers are separated by the "&" character.

Sequencing constraint examples

A set of examples will best explain these rules and illustrate the differences between the two schemes. In the following examples, we include both a routing diagram to illustrate the operation sequence numbering scheme and a successor table to illustrate the immediate successor operation scheme. In most of the examples, the operation numbers will be different. In those examples, both operation numbers will be displayed in the routing diagrams, with the immediate successor operation numbers in parentheses "()". Both operation numbers will also be included in the successor table. The operation sequence numbering scheme operation numbers will be labeled as OSN scheme operation number, and the immediate successor operation scheme operation numbers will be labeled as ISO scheme operation numbers.

If you have simple straight-line routings with no assembly or disassembly, then you only need to use root operation numbers. You can also describe one operation assembly or disassembly routing using only root operation numbers. Our first example shows two parallel operations, labeled 10, which can be performed independently, but both need to be completed before the last operation, labeled 20, can be started.


Immediate Successor Table								
OSN Scheme Operation Number	Immediate Successor Operation Number							
10	10	30						
10	20	30						
20	30							

The second example extends the previous one by allowing two sets of parallel operations. In this example, the first two operations, labeled 10, can be performed independently, but both need to be completed before the next two operations, labeled 20, which can be performed independently.



Immediate Successor Table								
OSN Scheme Operation Number	Immediate Successor Operation Number							
10	10	30 & 40						
10	20	30 & 40						
20	30	50						
20	40	50						
30	50							

The third example illustrates how to use the numbering schemes to allow a series of operations to be performed independently, as would normally be the case in typical industrial routings. This example has both assembly and disassembly features. In this example, the first two operations with the "1" suffix can be performed independent of the first two operations with the "2" suffix. You can use any value for a suffix, as shown in the disassembly portion of the example, where we skip to a "5" suffix.



Immediate Successor Table							
OSN Scheme Operation Number	ISO Scheme Operation Number	Immediate Successor Operation Number					
10.1	10	20					
20.1	20	50					
10.2	30	40					
20.2	40	50					
30	50	60 & 70 & 80					
40.1	60	100					
40.2	70	100					
40.5	80	90					
45.5	90	100					
50	100						

The fourth example shows a complicated bill of materials that requires several assembly operations at different levels. This numbering scheme illustrates the flexibility of representing complex routing structures.

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Immediate Successor Table								
OSN Scheme Operation Number	ISO Scheme Operation Number	Immediate Successor Operation Number						
10.1.1.1	10	20						
20.1.1.1	20	40						
10.1.1.2	30	40						
30.1.1	40	110						
10.1.2	50	60						
20.1.2	60	110						
10.1.3	70	80 & 90						
20.1.3.1	80	100						
20.1.3.2	90	100						
30.1.3	100	110						
40.1	110	130						
40.2	120	130						
50	130							

The final example illustrates a non-traditional network routing structure. Project management and maintenance environments frequently use these types of networks. This example illustrates the flexibility of the two numbering schemes.



Immediate Successor Table								
OSN Scheme Operation Number	Immediate Successor Operation Number							
10	10	20 & 30						
20.1.2	20	40						
20.1	30	40 & 50						
30.1.2	40	60						
30.1.1	50	60						
40	60							

Most industrial applications use the operation sequence numbering scheme because their routings tend to follow a straight line with occasional assembly operations. In addition, this scheme directly supports the routing numbering scheme used by most Enterprise Resource Planning (ERP) and Manufacturing Resource Planning (MRP) systems. The immediate successor operation scheme is generally only used when routings are more like a network as shown in our last example.

Tutorial: The routings for our tutorial system are simple routings in that only root numbers are required to describe the sequencing constraints. Thus, we have chosen to use the operation sequence numbering scheme. Recall that routing diagrams using this scheme were included in the previous chapter.

Material constraints

Material constraints typically are used to represent any make-to-stock or purchased items that constrain the scheduling of operations. This information is normally found in the

product bill of materials and indicates the amount of each material item required and where in the routing it is required. FactoryTalk Scheduler combines the bill of materials detail with the routing information.

You might think of a material as a bucket or bin containing inventory items of the same type. In FactoryTalk Scheduler, you can replenish or add to a material at the completion of any operation in a product routing, although in a make-to-stock environment, you would typically add to the material after the completion of the last operation of the product routing. You can also add to material based on the receipt of a purchase request for that item. It is not necessary to define an item as only a make-to-stock or purchased item; either method can replenish any material item. Material can also be consumed or removed at any operation in a product routing. When a material(s) is required by an operation, that operation will normally not be scheduled until all of the required material is available.

You can elect that material be consumed and/or produced in batches. For example, your production order batch size for a given material may be 1,000, but the actual material is transferred in batches of 100. By activating the batch transfer option for selective material actions, you can allow material to be available for consumption by other operations before the operation producing the item has been completed.

The replenishment or consumption of material is referred to as a *material action*. You can have as many material actions of either type as are required at any operation. For each material action, you must determine whether the replenishment or consumption is based on a quantity, which defaults to one, or the operation batch size. This determination is made at the operation level; thus, you can base the action on a quantity at one operation and the operation batch size at another operation. **Note that if an operation batch quantity has not been specified, this quantity defaults to the order quantity.**

In a typical ERP or MRP environment, all lower-level items have product routings that result in items being added to a material, based on the operation batch quantity. Higher-level items that require these materials are not scheduled until the materials become available. Thus, the MRP system takes care of the product explosion, netting of lower-level items, and the lead-time offset in scheduling the replenishment of materials. FactoryTalk Scheduler then makes sure that the required lower-level materials or items are available in developing a schedule.

When FactoryTalk Scheduler attempts to schedule an operation that requires a material, it will only schedule that operation at or after the time that the material level is sufficient to meet the requirements. If the scheduling horizon does not meet that condition, FactoryTalk Scheduler will first look to see if there are any unallocated orders that would produce the required material. If it finds such an order(s), it will first schedule that order(s), then schedule the operation requiring the material. If the order that produces the material requires another unavailable material, FactoryTalk Scheduler will look for an order to schedule as before. This process will be repeated as many times as required in an

attempt to allow the scheduling of the initial item. If there are insufficient materialreplenish orders to allow the final item to be scheduled, FactoryTalk Scheduler will not schedule the final item and will remove all items scheduled in the attempt to produce the material requirements.

Tutorial: In our tutorial, the following items will be modeled as materials, which are replenished as purchased items and consumed by the production of other products: Pedal and Chain Assembly, Wheels, Derailleur Assembly, Seat, and Brakes. The materials Frame, Handlebar, Neck Post, and Seat Post will be replenished by production orders and consumed by subassembly orders. The materials Finished Frame, Handlebar Assembly, and Seat Assembly will be replenished by production orders and will consume other materials. The Final Assembly and Pack order will consume many of the previously mentioned subassembly and purchased materials.

Fixture constraints

Fixture constraints can be used to model fixtures, tooling, molds, or special materialhandling devices that can be required for more than one successive operation. For ease of definition, we'll classify all of these types of devices as "fixtures." Fixtures differ from materials in that they are not consumed or produced, although you can vary the number of available fixtures over time.

A fixture(s) can be required at any operation and held across several following operations in the same process plan. One operation seizes a number of fixture units and a following operation releases the units. It's important to note that the fixture must be released in the same process plan in which it is seized. It is also possible to seize a fixture at the start of an operation and release it at the end of the same operation.

Tutorial: This concept is not illustrated in our tutorial.

Operation constraints

In addition to resource, sequencing, and material constraints, there are a number of operation constraints that can be included in a FactoryTalk Scheduler configuration. We won't attempt to cover all these special features in this chapter; we'll only highlight a few of the most commonly used features.

FactoryTalk Scheduler provides several features that can alter the way resource setups constrain the schedule. Most frequently used is the *sequence-dependent setup* feature that allows the setup time used for the current operation to be dependent on both the current and last operation. FactoryTalk Scheduler provides the ability to reference a setup matrix that includes these times when it is scheduling the operation.

Tutorial: We use this feature in our tutorial to represent the setup times at the Machine and Bend work cells.

A similar feature allows an operation process time to have a **resource product dependency**.

FactoryTalk Scheduler also provides several features that determine how **setups** and/or **teardowns** are scheduled. These allow for multiple times, which can be performed in parallel or sequential fashion. They also allow these activities to be performed in off-shift time periods.

Additional features provide more control on the **timing** between successive operations. These allow for the overlapping of operations at one extreme to the delay of the start of a subsequent operation at the other extreme.

You can also place limits on the **total span** of an operation to prevent a specific operation from spanning off-shift times, such as weekends.

These are just a sampling of the more commonly used special features that can be included in a FactoryTalk Scheduler configuration.

Summary

Now that we have reviewed the basic modeling features of FactoryTalk Scheduler using resource, sequencing, material, and operation constraints, let's turn our attention to a discussion of finite-capacity scheduling procedures.

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FactoryTalk Scheduler incorporates both an algorithmic and a simulation-based scheduler. This chapter describes finite-capacity scheduling in general, details the differences between these scheduling methods, and discusses how to select scheduling rules to accomplish your objectives.

Finite-capacity scheduling

Finite-capacity scheduling (FCS) is the process of creating a production schedule for a set of jobs that is to be produced using a limited set of resources. Each job is comprised of one or more operations (machine, form, paint, etc.) that must be performed in a specified sequence using the set of available resources (work-centers, machines, workers, etc.). A schedule assigns a starting and ending time to each operation and sequences the operations across the resources so that no resource conflicts occur. The operations are also assigned in a way that any sequencing constraints are respected.

FCS can be done using a manual planning board (sometimes called a Gantt chart) in which the available resources are listed down the left side. The operations are assigned to the resource rows and spaced horizontally within each row to represent the passage of time. Each operation is represented by a horizontal bar where the length of the bar represents the duration of the operation.

SCHEDULING EXAMPLE 1

The figure below shows a simple planning board with one of many possible operation schedules for three different jobs, denoted as Jobs A, B, and C. These jobs are produced using two resources denoted as Resources 1 and 2. The label within each horizontal bar denotes the job sequence (e.g., A-10 denotes Job A, Sequence Number 10). The data defining the operations for each job are shown in the accompanying table.



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Job	Sequence	Resource	Processing Time
A	10	1	3
A	20	2	4
В	10	2	5
В	20	1	2
С	10	1	3
С	20	2	4

In this simple example, Job A consists of two operations that are defined by sequence numbers 10 and 20 and must be performed in that order. Operation 20 cannot begin until Operation 10 is complete. Jobs B and C also contain two operations numbered 10 and 20, respectively. The processing time for each operation is also shown in the table.

It is important to note that this is merely one of several possible production schedules that can be generated for this very simple two-resource, three-job problem. In practical problems involving many different resources and many different jobs, the number of possible schedules is enormous. We clearly need an effective method for generating a good schedule that meets our production objectives.

Let's now turn our attention to the general FCS problem.

- Given: A set of jobs and a limited set of resources
- Find: A "good" schedule

Note that the objective is defined as determining a "good" schedule rather than an "optimal" schedule. We state our problem like this for two reasons. First, large scheduling problems (i.e., those with many resources and many jobs) are typically computationally challenging, and it's not possible to achieve an "optimal" solution in a reasonable time. Second, there are typically several simultaneous objectives (minimize tardiness, minimize cycle time, maximize resource utilization, etc.), and these are often in conflict. In a practical setting, therefore, we strive to find a "good" solution that balances these objectives and can be obtained with minimal computation.

We will describe two fundamentally different approaches to constructing a schedule. The first is algorithmic, or job-at-a-time sequencing. The second is simulation-based, or operation-at-a-time sequencing.

Algorithmic sequencing

Algorithmic sequencing is a simple method for schedule construction. The algorithmic sequencer selects a job and then puts each operation for that job on the planning board. It

repeats this process until all jobs (and therefore, all operations) have been loaded. Each operation is loaded on its specified resource at the first available time slot that satisfies the constraints for that operation.

In a **job-at-a-time** sequencer, the schedule is controlled by selecting the order in which the jobs are loaded onto the planning board. Hence, the key to the quality of the schedule that is generated by the algorithmic sequencer is the rule that is used for selecting the job-loading order.

SCHEDULING EXAMPLE 2

The job-at-a-time scheduling process is shown in the figures below. In this example, we first load Job A, then Job B, and finally, Job C.



Forward sequencing

There are a number of very simple heuristic rules that can be used to select the order for loading the jobs on the planning board. One rule that can be used for selecting the job order is to sort the jobs by a priority value that has been assigned to each job. Other possible sorting criteria are earliest due date, earliest release date, and smallest remaining slack time. None of these rules are optimal in a mathematical sense. Each rule represents a different strategy and focus in planning the jobs. For example, the due-date-related rules

(due date and slack time) focus on reducing the number of late jobs, whereas the prioritybased rule strives to complete the most important jobs as soon as possible.

In some applications, a given operation can be performed on two or more different resources. For example, a drilling operation might be performed on either of two drills. In such cases, the schedule in an algorithmic sequencer is first determined by the ordering of jobs, then by the rule that is used to determine to which resource a given operation is assigned during the loading process. Again, simple heuristic rules (e.g., assign the operation to the resource that will complete the operation first) can be used to determine the schedule.

Backward sequencing

Although a job-at-a-time sequencer typically loads each job working forward in time by starting with the first operation and continuing through the last operation, it is also possible to use this same sequencing scheme but reverse the procedure to work backward in time. In this case, the sequencer begins by loading the job's last operation to finish at its due date. It then continues by loading the job's preceding operation to finish at the start time of the last operation. This process is continued, working backward in time, until the first operation for the job is loaded. At this point, the sequencer then selects a new job to load and repeats the entire process, again starting with the last operation and working backward in time. It continues in this fashion until all jobs are loaded.

SCHEDULING EXAMPLE 3

The figure below shows a schedule generated by backward sequencing Jobs A, B, and C, where the vertical line on the right denotes the due date for all three jobs.



The advantage of a backward algorithmic sequencer is that it always generates a schedule that has no late jobs. However, the schedule may require start times that are infeasible; that is, the jobs must start before the current time. In essence, a forward job-at-a-time sequencer fixes the start times for a job and determines the end times (which may violate the due dates), whereas a backward job-at-a-time sequencer fixes the end times and determines the start times.

Although the idea of constructing a schedule that has no late jobs is appealing, backward sequencing has some practical limitations, even in cases where a feasible solution is generated. Backward scheduling shifts all jobs to the right on the planning board so that they start as late as possible while still meeting the due date. This means that there is no time buffer in the system, so any disruptions that occur (machine breakdowns, late material arrivals, etc.) will typically create late jobs. In addition, by postponing the use of our available capacity and waiting until the last minute to start each job, we give up the opportunity to consider additional jobs that may arrive later and need to be added to the schedule. For these reasons, many schedulers prefer a forward sequencer.

Bi-directional or bottleneck sequencing

It is also possible to use an algorithmic sequencer in a **bi-directional** or **bottleneck** mode. In this case, we select an operation somewhere in the middle of the job sequence and schedule the remaining operations using forward sequencing of the succeeding operations and using backward sequencing for the preceding operations. This is useful in cases where we have a bottleneck or highly utilized resource and we want to assign operations to this bottleneck resource and then load the upstream and downstream operations around it. The advantage of a bottleneck algorithmic sequencer is that it tends to minimize the cycle times of all jobs.

In summary, an algorithmic sequencer is a simple and fast method for loading a set of jobs on the planning board. The schedule is completely determined by specifying the order of jobs and a rule for selecting among resources.

Algorithmic job selection rules

Algorithmic job selection rules are used to determine the order in which the jobs are loaded onto the planning board. Most of them are simple ranking rules based on some attribute of the job. Brief descriptions of the standard algorithmic job selection rules are given below.

- Bottleneck: Ranking based on a secondary job selection rule. The forward and backward mode schedules all unallocated jobs with emphasis on those operations that require a bottleneck resource. The bi-directional mode only schedules jobs that require an identified bottleneck resource. The user can then schedule the remaining jobs using any of the available job selection rules.
- Due Date: Ranking based on the earliest job due date first.
- First-Come, First-Served: Ranking based on the position in which they are entered into the database.
- Ascending Order Property: Ranking based on the ascending value of a specified order property. The order property can be numeric or character, and it must be specific

as an available ranking order property. FactoryTalk Scheduler will automatically list all specified order properties.

- Priority: Ranking based on the smallest numeric priority. If you use this rule, a
 priority field must be included in the order database.
- Process Time: Ranking based on the sum of the job's operation times, the smallest sum being ranked first.
- Release Date: Ranking based on the earliest job release (or early start) date first.
- **Reverse Priority**: Ranking based on the largest numeric priority. If you use this rule, a priority field must be included in the order database.
- **Slack Time**: Ranking based on the smallest total job slack time.
- User Rule: Ranking based on a custom-written user rule. Multiple user rules can be added with the name of each display on a secondary selection list.

Simulation-based sequencing

Simulation-based sequencing provides an attractive alternative to algorithmic sequencing by providing a simple, yet very flexible method for constructing a schedule. In general, any schedule that is produced by an algorithmic sequencer can also be produced by a simulation-based sequencer. A simulation-based sequencer, however, can also consider many schedules that cannot be considered by an algorithmic sequencer.

In contrast to the algorithmic sequencer, the simulation-based sequencer selects and loads an operation-at-a-time. By loading individual operations rather than entire jobs, the simulation-based sequencer has finer control over the way the operations are loaded onto the planning board. This operation-at-a-time loading is the key to the added flexibility in schedule generation using the simulation-based sequencer.

A second fundamental difference between the algorithmic and simulation-based sequencer is that the simulation-based sequencer constructs the schedule in a single time pass by moving forward from one event time to the next. The simulation-based sequencer begins at the current time and loads all operations that can start now. Note that these operations do not come from a single job as in the case of the job-at-a-time sequencer, but can be taken from the entire set of jobs. Once all operations are loaded that can start at this event time, the simulation-based sequencer advances time to the next event—e.g., the first completion time for any operation on the planning board. In this case, a busy resource has just changed to idle; hence, the simulation-based sequencer attempts to load additional operations at this new event time. The simulation-based sequencer continues in this fashion, advancing time forward to the next event time and loading additional operations as resources become idle, until all operations have been loaded.

SCHEDULING EXAMPLE 4

The following sets of figures illustrate the simulation-based construction process. In each of the figures, the vertical line denotes the current value of simulated time.

STEP 1: LOAD OPERATION A-10 AND B-10



STEP 2: LOAD OPERATION C-10



STEP 3: LOAD OPERATION A-20



STEP 4: LOAD OPERATION B-20



STEP 5: LOAD OPERATION C-20



The first step in the simulation-based sequencer is to load all operations that can begin at the current time. In this example, Operation 10 for Job A (A-10) can be loaded on Resource 1, and Operation 10 for Job B (B-10) can be loaded on Resource 2. Next, the simulated time is advanced to the ending time of Operation A-10, and Operation C-10 is then loaded on Resource 1. Next, simulated time is advanced to the end of Operation B-10, and Operation A-20 is loaded on Resource 2. Next, simulated time is advanced to the end of Operation B-10, and Operation B-20 is loaded on Resource 1. Next, simulated time is advanced to the end of Operation C-10, and Operation B-20. Since no further operations remain to be loaded on Resource 1, simulated time is advanced to the end of Operation C-20, is loaded on Resource 2.

In contrast to the algorithmic sequencer, the simulation-based sequencer only moves time forward. It only advances time forward once all operations that are to be loaded at that time have been loaded. Hence, the simulation-based sequencer temporarily stops time and examines the entire job set, advancing to the next event time once all operations have been loaded. The algorithmic sequencer, on the other hand, is constantly moving back and forth in time as it loads all operations for each job. It starts at the current time and goes forward in time loading all operations for this first job. It then returns to the current time and again moves forward in time to load all operations for the second job. It continues in this fashion, moving forward and backward in time, until all jobs are fully loaded on the planning board. Hence, the algorithmic sequencer fixes a job and works across time, advancing to the next job once all operations have been loaded.

Selection rules

In a simulation-based sequencer, there are two types of selection rules that can be applied each time an operation is scheduled: an **operation selection rule** or a **resource selection rule**. If a *resource* becomes available and there are several available operations that require that resource, the operation selection rule is used to determine which operation is scheduled. If an *operation* becomes available and it can be scheduled on more than one resource, the resource selection rule is used to determine that resource. If both multiple operations and multiple resources are available, the operation rule is applied to select an operation, and then the resource rule is applied to select the resource.

Simulation-based sequencing can be set up so there is a single operation selection rule used to select all operations and a single resource selection rule to select all resources, or separate rules can be applied. If separate rules are used, they are associated with specific resource groups. For example, you may want to use a minimize setup rule for one group of resources and a due date rule for another.

Types of rules

There are two types of rules: **independent** and **dependent**. The use of independent rules allows different rules to be applied to the selection of operations and the selection of resources. Dependent rules require that the same rule be applied to the selection of both the operation and the resource. You can also develop and include your own rules. These are referred to as **user rules**, which will be included automatically on the list of available rules.

Although the operation-at-a-time loading scheme used by a simulation-based sequencer provides great flexibility in schedule generation, the key to tapping this flexibility is the development of rules for selecting the next operation to load or the resource on which it will be loaded. We discuss this in the following section.

Sequencing rules: The key to good schedules

The key to tapping the power and flexibility of simulation-based scheduling is the development of rules for guiding this two-step process. There are two basic categories of rules: **operation selection rules** (OSR's) and **resource selection rules** (RSR's). This section describes the basic concepts for incorporating rules into the FactoryTalk Scheduler simulation-based sequencer. One of the key advantages of a simulation-based sequencer is the ability to incorporate decision logic in the scheduling process based on rules for selecting operations and resources.

Operation selection rules

Operation selection rules, OSR's, are invoked in FactoryTalk Scheduler whenever at least one resource is idle and two or more operations can be loaded on that resource. The rule

determines which operation to load. This rule is the key factor that determines the quality of the resulting schedule.

RESOURCE GROUPS AND QUEUES

Before discussing the rule mechanisms in FactoryTalk Scheduler, we must first discuss the concept of Resource Groups and Queues. Each of the resources in the system may be assigned to one or more resource groups. These resource groups are used to represent situations where an operation can be performed on one of several alternative resources. Each resource group is assigned to one and only one queue that holds an ordered set of operations that are waiting to be loaded onto some member of the resource group. A queue holds operations that are in contention for resources within the resource group and that are subject to the same OSR. For example, a queue might be managed using a Critical Ratio rule, in which case, all operations within this queue are selected using this same rule.

TYPES OF OPERATION SELECTION RULES

There are two basic types of OSR's supported in FactoryTalk Scheduler: **standard** and **user-coded logic**.

Standard rules are hard-coded into FactoryTalk Scheduler. The user simply selects one of these rules from the menu of available rules. There are more than 20 standard rules built into FactoryTalk Scheduler. Different rules focus on different objectives; e.g., the Critical Ratio rule tends to minimize tardiness. These rules can be further classified as **static** or **dynamic** selection rules.

The static selection rules provide a simple sorting mechanism for ordering all waiting operations in the queue. These rules do not require re-evaluation after each simulation time advance. The parameters used to perform the operation selection are fixed. An example is the Earliest Due Date rule, since the due date never changes during sequencing. The first operation in the queue (as established by the static sort rule) is allocated to a waiting resource. Since the rule always selects the first waiting operation, this rule executes very fast.

In a dynamic selection rule, each operation in the queue is examined every time the rule is invoked. Therefore, we make our selection based on the current status of the job and the system. This mechanism fully accounts for any changes that occur as the result of time advances or events. An example is the Smallest Operation Slack rule since the operation slack value will change as a result of time advances during sequencing. Since dynamic selection rules require re-evaluation of each operation in the queue after each simulation time advance, it is slower than a static sorting rule.

User-coded logic rules provide a very powerful and flexible rule mechanism. User-coded logic rules are programmed by the user in Microsoft[®] Visual Basic[®] or other OLE-compliant language. In this case, the user explicitly searches the operations in the queue

and selects the desired operation using any appropriate logic. This type of rule gives complete flexibility in the selection of the next operation to load. In essence, if you can logically describe how an operation is selected, then you should be able to transform that logic into a user-coded logic rule.

Although the primary purpose of a given rule is to make a selection, the rule can be coded to perform other logic based on the selection. For example, the rule could both select a job and change the priority of the selected job from 2 to 1 by using the OLE Automation interface to write to the FactoryTalk Scheduler database.

RESOURCE SELECTION RULES

Resource selection rules, RSR's, are invoked in FactoryTalk Scheduler whenever an operation is being loaded onto a resource group and two or more eligible resources within the group are idle. The rule selects the resource within the group on which the operation is to be loaded. There are two basic types of resource selection rules: **standard** and **user-coded logic**.

Standard resource selection rules are hard-coded in FactoryTalk Scheduler. The user simply selects one of these rules from the menu of available rules.

User-coded resource selection rules are also supported. These rules are coded by the user in Visual Basic and provide complete flexibility in selecting a resource. Although the RSR Visual Basic procedure's primary purpose is to select a resource, it can also perform manipulation of the FactoryTalk Scheduler database using the OLE Automation interface. For example, if the operation is assigned to a specific machine, the state of the system could be modified in some way to account for this selection.

Picking the correct rule

The primary consideration in determining the operation and resource selection rules for an application is the criteria by which you measure a good schedule. For example, is your primary objective to create a schedule that meets the specified due date for all jobs or are you focused on improving facility utilization by reducing the non-productive time (e.g., setup time and equipment maintenance)?

Determining the fundamental scheduling objective is a prerequisite to selecting the appropriate rules to use. Once you have determined your objective, you select an operation and resource selection rule to accomplish that objective. Generally, this is done by first selecting an operation selection rule and then selecting an appropriate companion resource selection rule. In some cases, the associated resource selection rule is determined by the operation selection rule.

To help with this task, we have categorized the standard FactoryTalk Scheduler operation selection rules into four main categories that correspond to four distinct scheduling objectives. These categories include **Predefined Job Preferences**, **Minimum Job**

Tardiness, **Minimum Job Flow Times**, and **Maximum Facility Capacity**. We will discuss each of these core objectives and the corresponding FactoryTalk Scheduler operation and resource selection rules that support these objectives.

This categorization of the rules should help you narrow your choices based on your corescheduling objective. The selection of a specific rule within a category is based on the specific nature of the scheduling problem, the importance of a "good" schedule, and the time available for generating schedules. Each category of rules will contain some mixture of static and dynamic rules.

Predefined Job Preference

The Predefined Job Preference category of rules is focused on selecting the next operation based on the predefined job priority or a user-specified property field (e.g., cost). In general, each of these rules can be invoked by selecting the operation with the highest or lowest value of this characteristic. This category includes Highest Priority First, Lowest Priority First, Highest Order Property Field, Lowest Order Property Field, Dynamic Highest Order Property Field, Dynamic Lowest Order Property Field, Schedule File Order, Longest Waiting Time, Shortest Waiting Time, and Largest Processing Time.

- The **Highest Priority First** and **Lowest Priority First** are static rules that select the operation with the highest or lowest Priority value, respectively.
- The Highest Order Property Field and Lowest Order Property Field are static rules that operate similarly to the Priority rules, except that the selection is based on any user-specified property. The rule selects the job with the highest or lowest value of this property. For example, the Highest Order Property Field rule using a property field defined as Cost selects the job with the highest value of Cost. Since this is a static rule, it is assumed that the value of Cost does not change while the job is waiting to be processed for any jobstep.
- The Dynamic Highest and Lowest Order Property Field rules are dynamic versions of the Highest and Lowest Order Property Field rules. Although these rules execute more slowly, they accommodate situations where the value of the property field may change while the job is waiting.
- The Schedule File Order rule is a static rule that selects the operation based on the order that it was entered into the database. This rule is similar to a first come, first served rule.
- The Longest and Shortest Waiting Time rules are dynamic rules that select the operation based on the amount of time that the job has been waiting to be scheduled.
- The Largest Processing Time rule selects that operation with the largest processing time.

The predefined job preference rules are generally used in situations where the characteristic of the job (e.g., priority or cost) is the overriding issue in scheduling, rather than job due dates or facility utilization. Since these rules ignore due dates, they are typically more applicable in make-to-stock rather than make-to-order environments.

Minimum Job Tardiness

In many make-to-order environments, the overriding scheduling objective is to ensure that every job is completed by its assigned due date. The Minimum Job Tardiness rules are focused on creating a schedule that minimizes the job tardiness. The rules in this category include Earliest Due Date, Smallest Operation Slack Time, Smallest Order Slack Time, Critical Ratio, and Actual Critical Ratio.

The simplest of these rules is the Earliest Due Date. This is a static rule that selects the job with the earliest due date. Although this rule executes very fast, it is generally less effective than the other rules in this category for reducing job tardiness.

All of the other rules in this category are dynamic rules based on the calculation of a *slack time*. The slack time is defined as the difference between the due date and the earliest job completion time.

- The Smallest Order Slack Time rule selects the operation whose parent job has the least amount of slack time. This is based on the premise that this is the job that is most likely to become late if it is not selected.
- The **Smallest Operation Slack Time** rule is based on the average slack time per operation (computed as the slack time for the job divided by the number of remaining operations) rather than the remaining slack time for the job. The basic idea behind this form of the slack-time-based rules is that each remaining operation has an inherent risk, and the job with the smallest slack time per operation is the most critical in terms of its likelihood of becoming late. Hence, if we were selecting between two jobs with the same slack time, we would select the job with the largest number of remaining operations, since this is the highest-risk job in terms of smallest slack time per operation.
- The last variation of the slack-time-based rules is the **Critical Ratio** rule. This rule selects the operation whose parent job has the smallest critical ratio. The critical ratio is defined as the ratio of the demand time divided by the supply time. The demand time is defined as the amount of time remaining to complete the order to meet the due date. The supply time is the remaining work time to complete the order. A ratio less than one implies the order is already behind schedule, a ratio greater than one implies the order is an a ratio of one implies the order is on schedule.

The Critical Ratio rule is similar in spirit to the Smallest Operation Slack Time rule in that it uses the slack-time calculation but interprets it differently to account for the remaining

work (rather than number of operations) to be done. The basic premise is that the remaining slack time itself is not as important in determining the most critical job as it relates to the remaining work to be done. If we have a lot of remaining work, then we need a larger slack time to ensure that we will not be late.

Minimum Job Flow Times

In some environments, the critical issue is to schedule the facility efficiently to minimize the average time that a job spends in the facility. The rules in the Minimum Job Flow Times category ignore the job due date and are focused on reducing the time that the job spends in the system. The rules in this category include Smallest Processing Time, Fewest Remaining Operations, and Smallest Work Remaining.

All of the rules in this category are based on the concept that by processing the "shortest" job first, the average job flow time for all jobs is reduced. To illustrate this concept, consider the processing of two jobs, A and B, on a single machine. Let us assume that Job A requires 4 hours to process, and Job B requires 10 hours to process. If we process A and then B, Job A starts immediately and completes at Time 4, yielding a flow time of four. Job B starts at Time 4, and ends at Time 14, yielding a flow time of 14. The average flow time in this case is 9. If we reverse the order, the flow time for B is 10, and the flow time for A is 14, producing a higher average flow time of 12. Although this is a very simple example, the basic concept generalizes to complex scheduling applications involving many machines and many different jobs. The rules in this category are all built on this same concept of processing the shortest job first and only differ in how they determine the shortest job.

- The **Smallest Processing Time** rule is a static rule that selects the operation with the shortest operation time.
- In contrast, the Smallest Work Remaining rule is a dynamic rule that selects the operation whose parent job has the smallest remaining work. The remaining work is defined as the sum of operation times for all remaining operations for this job.

The Smallest Processing Time rule examines the processing time for a single operation, whereas the Smallest Work Remaining rule examines the processing times for all remaining operations.

• The **Fewest Remaining Operations** rule is similar to the Smallest Remaining Work rule, except that this rule is based on the number of remaining operations rather than the sum of the processing times.

Maximum Facility Capacity

In some make-to-stock environments, the critical issue is to schedule the facility efficiently to maximize the overall production capacity of the facility. The rules in the

Maximum Facility Capacity category ignore the job due date and are focused on generating a schedule that is efficient in terms of increasing the effective capacity of the facility. The rules in this category include Least Setup Time, Campaign Sequence Up, Campaign Sequence Down, Campaign Sequence Cycle, and Least Setup With Campaign. In addition, each of these rules has an associated Timed rule.

All rules in this category focus on maximizing the facility capacity by reducing changeover cost within the facility. This changeover cost can be in the form of a sequencedependent setup time that is required between each pair of operations, or in the form of maintenance that is required if we fail to follow certain prescribed operating policies (e.g., moving from wide to small widths on a roller). In either case, we are striving to eliminate any unnecessary, unproductive time in the facility.

In cases where we must look at the changeover cost in terms of a sequence-dependent setup time between successive operations for an entire sequence of operations, we can use the campaign rules. For example, in mixing paint, we typically want to move progressively from light colors to dark colors in a predefined sequence. This is done to avoid the expense of fully cleaning the mixing tank when going from a dark to a light color. In some of these cases, we have a pre-specified sequence that we want to follow. For example, we may want to process orders in the color sequence A, B, C, D, and E, referred to as a campaign sequence. If we have just processed color A, we would first look for other orders that also have color A. If none are currently available, we would look for orders with color B, followed by color C, etc.

The campaign rules provide this capability. These rules allow us to specify a campaign value (e.g., paint color, curing temperature, etc.) that is associated with each order/ operation and dynamically build campaigns that automatically either increase, decrease, or cycle this value up and down. The dynamic campaign rules all work in conjunction with the campaign sequence resource selection rules that select the appropriate resource whose change in campaign value is the smallest.

- In the case of an increasing campaign strategy, the **Campaign Sequence Up** rule selects the operation that has a campaign value that is greater than or equal to the campaign value of the last selected operation. For example, if we are building an increasing campaign on part size, the rule selects an operation that has the same or next highest size. If none of the waiting operations have the same or larger value, the rule starts a new campaign by selecting the operation with the smallest campaign value.
- The Campaign Sequence Down rule is similar, but selects operations whose campaign value is the same or smaller than the campaign value of the last selected operation.
- The Campaign Sequence Cycle rule alternates back and forth between an increasing campaign and a decreasing campaign. If the campaign is increasing, it will continue to

increase until no orders remain with the same or larger campaign value. When this occurs, the rule then switches to a decreasing campaign and begins selecting orders that have the same or smaller campaign value. When all such orders are exhausted, it then returns to an increasing campaign strategy. This rule continues in this fashion, repeatedly cycling between an increasing and decreasing campaign strategy. This is typical in many industries using ovens or furnaces to treat metals. In such cases, the temperatures are incrementally raised to the highest level, then lowered.

- The Least Setup With Campaign rule combines the concept of the Least Setup Time rule with the Campaign Sequence Cycle rule. The operation with the least setup time and the closest campaign value is selected. The campaign values are only used to resolve ties in setup.
- The associated **Timed** rules only consider operations with job due dates that fall within a specified time horizon. The time horizon value must be specified in the database. For example, you may want to follow a color campaign, but you only want to consider the jobs that are due within the next week. This type of rule attempts to minimize the color changeover, without having a campaign so long that it results in overdue jobs.

Resource rules

Although the operation selection rule plays a primary role in determining the overall quality of a production schedule, the resource selection rule can also play an important role in this process. In the case of the Least Setup Time and the campaign operation selection rules, the resource selection rule is automatically determined by the operation selection rule (e.g., by selecting the Least Setup Time operation rule, the Least Setup Time resource selection rule is automatically selected). However, for all of the remaining operation selection rules, you must specify one of the available resource selection rules.

- Earliest End Time is the default resource selection rule. It selects the resource that will finish the operation first. The basic strategy with this rule is to finish the operation as soon as possible; therefore, this rule follows a similar strategy to the operation selection rules in the minimum flow-time category.
- The Earliest Start Time rule selects the resource that will start an operation first. This rule focuses on reducing idle time on resources, but may do so at the expense of increasing the flow time or assigning operations to less efficient resources.
- The Latest End Time rule selects the resource that will complete the operation last.
- The Same As Previous Operation rule attempts to select the same resource that was used for the previous operation. If the resource is not included in the valid resource group for this operation, the default Earliest End Time rule will be applied.

- The Non-Bottleneck Earliest End Time rule selects the non-bottleneck resource that will complete the operation first. If there are no identified bottleneck resources in the valid resource group, this rule defaults to the Earliest End Time rule.
- The Non-Bottleneck Earliest Start Time rule selects the non-bottleneck resource that will start the operation first. If there are no identified bottleneck resources in the resource group, this rule defaults to the Earliest Start Time rule.

Summary of independent operation selection rules

Brief descriptions of the standard independent operation selection rules are given below.

- Earliest Due Date: The operation with the earliest due date (may be order due date) is selected.
- Highest Priority First: The operation with highest priority (lowest value) is selected.
- Lowest Priority First: The operation with lowest priority (highest value) is selected.
- Highest Order Property Field: The operation with the highest (or largest) order property field value is selected. The order property can be numeric or character, and it must be specified as an available ranking order property. FactoryTalk Scheduler will automatically list all specified order properties.
- Lowest Order Property Field: The operation with the lowest (or smallest) order property field value is selected. The order property can be numeric or character, and it must be specified as an available ranking order property. FactoryTalk Scheduler will automatically list all specified order properties.
- Dynamic Highest Order Property Field: The operation with the highest (or largest) order property field value is selected. The order property can be numeric or character, and it must be specified as an available ranking order property. FactoryTalk Scheduler will automatically list all specified order properties.
- Dynamic Lowest Order Property Field: The operation with the lowest (or smallest) order property field value is selected. The order property can be numeric or character, and it must be specified as an available ranking order property. FactoryTalk Scheduler will automatically list all specified order properties.
- Schedule File Order: The operation that appears first in the order file is selected. This rule is similar to a first come, first served rule based on the order file.
- Critical Ratio: The operation with the smallest critical ratio is selected. Critical ratio is calculated as the amount of time remaining to complete the order to meet the due date (demand time) divided by the remaining work time to complete the order (supply time).

- Fewest Remaining Operations (static): The operation whose job has the fewest remaining operations is selected.
- Longest Waiting Time: The operation that has been waiting the longest will be selected.
- Shortest Waiting Time: The operation that has been waiting the least will be selected.
- Largest Processing Time: The operation with the largest processing time will be selected.
- Smallest Processing Time: The operation with the smallest processing time will be selected.
- Smallest Operation Slack: The operation with the smallest operation slack is selected. Job slack is defined as the time remaining until the job due date, minus the remaining work. Operation slack is defined as the job slack divided by the remaining number of operations to complete the job.
- Smallest Order Slack: The operation with the smallest job slack is selected. Job slack is defined as the time remaining until the job due date, minus the remaining work.
- Smallest Work Remaining: The operation with the smallest remaining process time (for all operations required to complete the job) is selected.

Summary of standard independent resource selection rules

Brief descriptions are given below.

- Earliest End Time: The resource that will complete the operation first will be selected.
- Earliest Start Time: The resource that will start the operation first will be selected.
- Latest End Time: The resource that will complete the operation last will be selected.
- Same As Previous Operation: The resource that was used for the previous operation will be selected.
- Non-Bottleneck Earliest Start Time: The non-bottleneck resource that will start the operation first will be selected. If there are no identified bottleneck resources in the resource group, this rule will default to the Earliest Start Time.

Summary of dependent selection rules

Brief descriptions of the standard dependent selection rules are given below that describe the operation selection rule. A corresponding resource selection rule, which respects the operation selection rule, is automatically assigned.

- **Campaign Sequence Cycle**: The operation with the same or next highest (lowest) campaign value is selected. The sequence starts with the lowest value and selects operations with increasing campaign values. When there are no operations with higher values, the sequence is reversed and the next lowest value is selected.
- **Campaign Sequence Down**: The operation with the same or next lowest campaign value is selected. The sequence starts with the highest value and selects operations with decreasing campaign values. When there are no operations with lower values, the operation with the highest value is selected.
- Campaign Sequence Up: The operation with the same or next highest campaign value is selected. The sequence starts with the lowest value and selects operations with increasing campaign values. When there are no operations with higher values, the operation with the lowest value is selected.
- Least Setup With Campaign: The operation with the least setup time and the closest campaign value is selected. The campaign values are only used to resolve ties in setup.
- Least Setup Time: The operation with the least setup or changeover time is selected.

The following dependent rules are campaign and setup rules that only consider the operations with job due dates that fall within a rolling-time horizon, specified by a *timed offset* value in the database. You can think of this as a time window that rolls forward as the simulation-based sequencer advances time. Only operations that have due dates that are earlier than the current simulation-based sequencer time plus the timed offset are considered. If at any time advance there are no operations with due dates that fall within this rolling-time window, then all available to-be-scheduled operations with due dates beyond the window will be considered. Brief descriptions of the standard independent operation selection rules are given below.

- Timed Campaign Sequence Cycle: The operation with the same or next-highest (lowest) campaign value is selected. The sequence starts with the lowest value and selects operations with increasing campaign values. When there are no operations with higher values, the sequence is reversed and the next lowest value is selected.
- Timed Campaign Sequence Down: The operation with the same or next-lowest campaign value is selected. The sequence starts with the highest value and selects operations with decreasing campaign values. When there are no operations with lower values, the operation with the highest value is selected.
- Timed Campaign Sequence Up: The operation with the same or next-highest campaign value is selected. The sequence starts with the lowest value and selects operations with increasing campaign values. When there are no operations with higher values, the operation with the lowest value is selected.

- **Timed Least Setup With Campaign**: The operation with the least setup time and the closest campaign value is selected. The campaign values are used only to resolve ties in setup.
- **Timed Least Setup Time**: The operation with the least setup or changeover time is selected.

Custom sequencing

Custom sequencing allows the user to take total control of the scheduling activity. This can take the form of a specialized simulation approach or may involve the use of optimization routines or searches to develop the entire schedule. FactoryTalk Scheduler provides an extensive list of objects that can be utilized to query the schedule status, search unscheduled operations, and so forth.

Summary

In this chapter, we provided a brief overview of the various methods available for schedule construction and the rules that add the desired flexibility and control to the scheduling process. As we move into Chapter 6, we'll begin to use FactoryTalk Scheduler to apply these concepts through our tutorial system.



Using FactoryTalk Scheduler

In Chapter 3 we introduced our tutorial system, and in Chapter 4 we discussed the basic FactoryTalk Scheduler modeling features and how they relate to our tutorial system. Chapter 5 was devoted to a general discussion of the various scheduling procedures available, along with their brief descriptions. Chapter 6 now covers the basics of using the FactoryTalk Scheduler system and shows you how to use many of these concepts in the context of our tutorial system.

Basic interactions

FactoryTalk Scheduler is a true Microsoft[®] Windows[®] operating system application, so you should be familiar with many common operations like menus, toolbars, window-clicking, double-clicking, drag-and-drop, and other standard interactions using both the mouse and the keyboard.

To simplify our descriptions of user interactions, we will use the notation M > S > C to signify that you should pull down the menu (M), select (S) from that menu, and then choose (C) from the cascading menu, if any. "Ctrl+character" will mean to hold down the Ctrl key and press the "designated keyboard character." Many of the FactoryTalk Scheduler operations or functions are similar to those in other Windows applications, so we will not always cover every menu option. Many FactoryTalk Scheduler functions can be launched using either a menu option or a toolbar button, so before you start, you may want to select the **View > Customize Toolbars** menu option and activate most of the toolbars.

Launch and save an application

You can launch FactoryTalk Scheduler through the Start menu or by using the FactoryTalk Scheduler shortcut icon that is included in the FactoryTalk Scheduler setup. If you use the shortcut, you might want to check the icon properties to ensure that "Target" and "Start in" are pointed to the correct directories.

There are two ways to load an application: either by using the FactoryTalk Scheduler "*fcs*" file or by *attaching a database* directly. The *fcs* file tells FactoryTalk Scheduler where to find the correct database. It also stores the planning horizon settings and your window arrangement. In general, we recommend that you use the *fcs* file.

The normal installation of FactoryTalk Scheduler results in the creation of the FactoryTalk Data Model (FDM) database for our BizBikes tutorial system. The installation will not generate the corresponding *fcs* file.

Thus, the first time you load a new FactoryTalk Scheduler application, you will have to set up your planning horizon and attach your database. If you inadvertently set up the wrong planning horizon or decide later that you need to change it, you can make changes the next time you load the schedule.

There are six different save options available in the File menu; Save, Save All, Save As, Save FCS, Save Log, and Save Report Data. The Save and Save As options save the active files with their current name and location, including the *fcs* and the FactoryTalk Scheduler database files. These options do not update report data or log information. The Save All option saves the same information as the Save option, but also saves the report data. It does not save the log information. The Save FCS option saves only the information contained in the *fcs* file. The Save Log option only saves the log information. Finally, the Save Report Data option saves only the report data (not the *fcs*, FactoryTalk Scheduler database files, or the report data).

Set the planning horizon

Set Planning Horizor		? ×
☑ <u>U</u> se Fixed Start D	ate	
<u>Fixed</u> Start Date	Feb 10, 200	03 12:00 AM 🕂 💌
<u>H</u> orizon Start Offset	1	Days
H <u>o</u> rizon End Offset	18	Days
OK	Cancel	<u>H</u> elp

Let's now perform the setup for our tutorial system and attach the database. Selecting the **File > New** menu option will open the Set Planning Horizon dialog. We want to check the "Use Fixed Start Date" and set that date to Monday, February 10, 2003. We selected this date because it is consistent with the dates in our tutorial system. If you uncheck the "Use Fixed Start Date," FactoryTalk Scheduler will set the

planning horizon based on the current time and date on your computer.

You can type in the desired date and time, or you can click on the drop-down arrow and select the correct date from the calendar that appears, as shown.

The double arrows (<< or >>) at the top allow you to change the year. The single arrows (< or >) change the month. Double-clicking on the desired day sets that date as the Fixed Start Date. Now set the "Horizon Start Offset" to 1 day and the "Horizon End Offset" to 19 days. The result is a planning horizon of 20 days, beginning on Sunday, February 9, 2003, and ending on Thursday, February 27, 2003. FactoryTalk Scheduler will also assume that the current date and time for the planning



board is February 10, 2003, 12 AM, because we selected the Fixed Start Date option. Now click **OK** to accept these settings. This will open a blank Sequence Overview window, which reflects the set planning horizon. Next we will attach the database.

Attach a database

Select the **Database > Attach** menu option to open the Connect To Database dialog that allows you to select the database file. Since the BizBikes tutorial uses a SQL database, you want to select or highlight the Microsoft SQL Server option. Then click the **Next** button, which will take you to the Server dialog.

Connect To Database			×
Database Type Select database type			
Select the type of databa	ase you want to connect to:		
Microsoft SQL Serve	r		
C Oracle			
	< <u>B</u> ack	Cancel Help	

The Server dialog requires that you enter your server name, user name, and password. Click the **Next** button to select the database.

Connect To Database	×
Microsoft SQL Server Parameters Select SQL Server connection parameters	I
Specify the following to connect to SQL Server data: 1. Enter server name: SERVER NAME	
2. Enter logon information for the server: Use <u>W</u>indows Integrated security Use a specific user name and password:	
< <u>B</u> ack <u>N</u> ext >	Cancel Help

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Select the database from the drop-down list (BizBikes) and click the Next button.

Connect To Database	×
Microsoft SQL Server Parameters Select SQL Server connection parameters	Ì
• Select the database on the server:	
BizBikes	
C Attach a database file as a database name:	
Using the <u>fi</u> lename:	
< <u>B</u> ack <u>N</u> ext >	Cancel Help

The last dialog requests that you choose a Table Map. Select the default and click on the **Finish** button to load the database.

Select Table Hap			×
Detabase Table Map Select database table map			Ì
Choose a Table Map	Default		•
Use FactoryTalk Web Server 0	ionfigured Diatabase		
< Bac	k Finish	Canoel	Help

Once all the data is read in, our resource names will be displayed down the left side of the Sequence Overview window, as shown below. Note that the board will be empty until we add jobs to the schedule.

E Sequence Overvi	ew (02	/09/20	03 00:	00 - 02	/28/2	003 00):00) -	BizBil	es 6.f	C-S			_ 0	×
0	2/09/2	003	12.00	02 19-00	/10/20	08-00	12-00	02 19:00	2/11/20	03 06:00	12:00	02 19:00	2/12/20	03
Assembly and Pack Area					202.	00,00	.1400	. 19,99						
Assembly and Fack Area														
Assembly and Pack Area	2													
Bender														
Cutter														
Finisher														
Labor														
Machiner														
Cubaccombly Area 1														
Subassembly Alea 1														
Subassembly Area 2														
Welder	•	1											•	-

Im Unallocated Orders/Ops - Sequence Overview (02/09/2003 00:00 - 02/28/2003 00:00) - BizBikes 6.fcs									
Handlebar 1	Neck Post 3	SHP Blue Finished Frame 2	SHP Red Finished Frame 1	SSD Frame 1					
Handlebar 1	Neck Post 3	SHP Blue Finished Frame 2	SHP Red Finished Frame 2	SSD Frame 1					
Handlebar 1	Neck Post 3	SHP Blue Finished Frame 3	SHP Red Finished Frame 2	SSD Frame 1					
Handlebar 2	🗎 Seat Assembly 1	SHP Blue Finished Frame 3	SHP Red Finished Frame 3	SSD Frame 1					
Handlebar 2	🗎 Seat Assembly 2	SHP Blue Finished Frame 4	SHP Red Finished Frame 3	SSD Frame 2					
Handlebar 2	🗎 Seat Assembly 3	🗎 SHP Blue Finished Frame 4	🗎 SHP Red Finished Frame 4	SSD Frame 2					
Handlebar 3	🗎 Seat Assembly 4	🗎 SHP Frame 1	🗎 SHP Red Finished Frame 4	SSD Frame 2					
Handlebar 3	🗎 Seat Assembly 5	🗎 SHP Frame 1	🗎 SSD Blue 1	SSD Frame 2					
Handlebar 3	🗎 Seat Post 1	SHP Frame 1	🗎 SSD Blue 2	SSD Red 1					
Handlebar Assembly 1	📄 Seat Post 1	SHP Frame 1	🗎 SSD Blue 3	SSD Red 2					
Handlebar Assembly 2	🗎 Seat Post 2	🗎 SHP Frame 2	🗎 SSD Blue 4	🗎 SSD Red 3					
Handlebar Assembly 3	🗎 Seat Post 2	🗎 SHP Frame 2	🗎 SSD Blue 5	SSD Red 4					
Handlebar Assembly 4	🗎 SHP Blue 1	🗎 SHP Frame 2	🗎 SSD Blue 6	SSD Red 5					
Handlebar Assembly 5	SHP Blue 2	🗎 SHP Frame 2	🗎 SSD Blue 7	SSD Red 6					
Neck Post 1	🗎 SHP Blue 3	SHP Red 1	🗎 SSD Blue 8	SSD Red 7					
Neck Post 1	SHP Blue 4	🗎 SHP Red 2	🗎 SSD Blue Finished Frame 1	SSD Red 8					
Neck Post 1	🗎 SHP Blue 5	🗎 SHP Red 3	🗎 SSD Blue Finished Frame 1	SSD Red Finished Frame 1					
Neck Post 1	SHP Blue 6	SHP Red 4	SSD Blue Finished Frame 2	SSD Red Finished Frame 1					
Neck Post 2	🗎 SHP Blue 7	🗎 SHP Red 5	🗎 SSD Blue Finished Frame 2	SSD Red Finished Frame 2					
Neck Post 2	🗎 SHP Blue 8	🗎 SHP Red 6	🗎 SSD Blue Finished Frame 3	SSD Red Finished Frame 2					
Neck Post 2	🗎 SHP Blue 9	SHP Red 7	SSD Blue Finished Frame 3	SSD Red Finished Frame 3					
Neck Post 2	🗎 SHP Blue Finished Frame 1	🗎 SHP Red 8	🗎 SSD Blue Finished Frame 4	SSD Red Finished Frame 3					
Neck Post 3	SHP Blue Finished Frame 1	🗎 SHP Red Finished Frame 1	SSD Blue Finished Frame 4						

Now we'll open the Unallocated Jobs window by using the **View > Unallocated Orders/Operations** window menu option. The resulting window is represented below.

Create the fcs file

The Unallocated Jobs window contains all operations for all the jobs currently waiting to be scheduled, so now we'll create our *fcs* file by using the **File > Save As** or the **File > Save** menu option. The default file name is always *Scheduler 1.fcs*. However, we recommend that you name this file *BizBikes.fcs*, so that if you create other scheduling applications you will always know to which application this file belongs. When naming your files, it is not necessary to include the *fcs* extension since FactoryTalk Scheduler automatically appends it.

The next time you want to open this file, simply use the **File > Open** menu option and select the *fcs* file name. The latest version of your schedule file will open with the same settings that we originally requested in the setup window. This file contains not only the setup information, but also the directory information of where to look for the FactoryTalk Scheduler database.

When you open the file using the *fcs* file name, the Set Planning Horizon dialog will be displayed. This allows you to change the planning horizon before the data is read in.

The *fcs* file also contains the information about the look and feel of the application. This includes the font type, font colors, resource colors, etc., that you see when you view the Sequence Overview window. The tutorial system assumes the default settings, which can be changed using the **View > Properties** menu option. If you change any of these settings

and save the *fcs* file, these changes will automatically be used when you recall an application using the *fcs* file.

Develop the shift or time patterns

Shift or time patterns constrain the availability of resources over time. These constraints include off-shift, vacation, holidays, preventive maintenance, breakdowns, etc.—times where resources are unavailable. For normal resources such as machines, it can also include efficiencies that may vary during the available times. For example, a work center may perform at a lower efficiency during the third shift or at the end of a shift. These patterns also include the number (or capacity) available for adjustable pooled resources.

The BizBikes tutorial system is already configured with the two-shift five-days-a-week time pattern described in Chapter 3. To view these time patterns, you should select the **View > Time Pattern** menu option. This will display the Time Pattern window shown below.

1								
	E Time Pattern							
	02/	09/2003 02	/10/2003	02/11/2003	02/12/2003	02/13/2003		
	(00,00 06,00 12,00 18,00	0000 06:00 12:00) 18;00 00;00 06;00 12;00	0 18,00 00,00 06,00 12,00	18;00 00;00		
	Assembly and Pack Area 1 Time Pattern	Off Shift	Off Shift Efficienc	y 1.000000 COff Shift Efficient	sy 1.000000 (Off Shift Efficienc	y 1.000000 (Off 📥		
	Assembly and Pack Area 2 Time Pattern	Off Shift	Off Shift Efficienc	sy 1.000000 COff Shift Efficient	sy 1.000000 (Off Shift Efficienc	y 1.000000 (Off		
	Bender Time Pattern	Off Shift	Off Shift Efficienc	cy 1.000000 COff Shift Efficience	cy 1.000000 (Off Shift Efficienc	y 1.000000 (Off		
	Cutter Time Pattern	Off Shift	Off Shift Efficience	y 1.000000 COff Shift Efficience	y 1.000000 (Off Shift Efficienc	y 1.000000 (Off		
E	1					• //.		

There are three different editors available for developing time patterns. All three editors can be accessed using the **Database > Time Pattern** menu options. The Time Pattern Editor is used to develop the basic time or shift patterns. The Exception Editor is used to overlay exceptions (holidays, preventive maintenance, breakdowns, etc.) on previously developed time patterns. The Composite Editor is used to associate a developed time pattern with a specific resource. Information on how to use these editors is given in Appendix D.

Develop a schedule

At this point, we'll develop a schedule for our tutorial system using one of FactoryTalk Scheduler's many scheduling options. To create our first schedule, let's use the **Sequence** > Forward > Release Date menu option (one of the automatic scheduling rules included in FactoryTalk Scheduler). Selecting this option removes all of the operations from the .



Unallocated Jobs Window and places them on the planning board. The resulting schedule is shown next.

Each scheduled operation on the planning board is represented by a colored bar. You will note that all the operations that comprise an order are the same color, and the order name appears on each bar. Unfortunately, it's difficult to read many of the order names because each bar is scaled to represent the operation time. You can modify this view by using the **View > Zoom To Fit**, **View > Zoom In**, or **View > Zoom Out** menu options.

The Zoom To Fit is a toggle option that shows the entire time horizon in a compressed format. When the Zoom To Fit option is toggled on, the Zoom In and Zoom Out options are disabled. For our tutorial system, the Zoom To Fit option provides a clear view of all the orders and operations. For larger systems with a large number of orders and a longer time frame, this view may compress or reduce the size of each operation to the point where it provides very little information.

If your current view has the Zoom To Fit option on, you may want to toggle it to the off position. This will allow the other two zoom options to be used. By zooming in several times, many of the order names will become readable, although you will be looking at a much smaller section of the total schedule.

In generating our schedule, we only used one of the numerous automatic methods provided by FactoryTalk Scheduler. In the next chapter, we will look at how you can compare different schedules.
The Attributes window

You can get more information about each operation by placing your mouse cursor on an operation and right-clicking to reveal a dialog with several options. Click on the **Attributes** option to show the Attributes window. You can also open this dialog by double-clicking on the selected operation.

Let's select the second operation that is scheduled for the Cutter resource—operation "Cut Handlebar Tubing" for order "Handlebar 1." The Attributes window, shown below, has tabs that allow you to view the Attributes of the order, operation, resource, additional resources, material actions, and fixture actions for the selected operation.

Order	Op	eration Resource	5115
MFG_Order_Name		Handlebar 1	
Material		Handlebar / Handlebar Plan	
Custom_Material_Name			-
Customer_Name		MRP	1
Priority		3	1
Release_Date		Feb 11, 03 11:00 PM	
Due_Date		Feb 14, 03 11:00 PM	1
Start_Date		Feb 11, 03 11:00 PM	1
End_Date		Feb 13, 03 12:44 PM	-

Leaving this window open and clicking on another operation displays the information for the new operation in the window. By clicking through the operations on the planning board, you can determine how each order is scheduled. If we want to look at all the operations for the "Handlebar 1" order, we must know the routing for that product in order to find the operations on the board. Although the difference in order color helps distinguish the operations, it can be a rather daunting task to follow the process when you have a large number of operations and resources.

The Order Trace View window

An easier way to view individual orders is to use the **View > Order Trace** window menu option to open the Order Trace View window, shown below. This displays the same information as the Sequence Overview window, except the operations are displayed by order, rather than by resource. It also provides an easy mechanism for following the operations of an order through the system.

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If you want to view the schedule of the Handlebar 1 order in the context of the entire schedule, you can use the **View > Find Order** menu option. Before you select this option, you need to select the order name by using the drop-down feature located in the Show toolbar, as displayed below.



When you activate this option, all operations that are not a part of the Handlebar 1 order are grayed out, making it easy to find the Handlebar 1 operations, as shown below. Repeating this selection takes you back to the normal sequencer view.



Use operation overlap

The default view for the Sequence window is structured to provide an overview of the entire schedule. In many implementations, the default view does not show all the information about the schedule. For example, in our tutorial, we have a resource that can have multiple operations being performed at the same time. There are three Labor resources that could be working on different operations.

You can get a complete picture by placing your cursor on the Labor resource, rightclicking, and selecting the **Toggle Overlapping Operations** menu option. This will change the display so all operations for the Labor resource are shown.

Another factor in looking at a schedule is the timing of shift changes. In our tutorial, our resources are only available during the first two shifts. You can see all the availability patterns by opening the Time Pattern, but it does not show the scheduled operations. If you want to see the time patterns of select resources, you can right-click on a resource and select the **Overlay Time Patterns** menu options. This causes the resource shift pattern to be overlaid with the schedule operations. If you toggle the overlapping operations for the

Sequence Overview (02/09/2003 00:00 - 02/28/2003 00:00) - BizBikes 6.fcs _ 🗆 × 02/12/2003 02/13/2003 00;00 06;00 12;00 18;00 00;00 • Bender Cutter SSD Red 2 fficiency 1.000000 SHP Frame 2 andlebar ' Neck Post Finishe SD Blue Finishe Handlehar Off SOff Shift abo SHP Blue 2 SHP Red SSD Blue SSD Red 2 SSD Blue Machine SHP Frame 1 Neck Post 1 F

Labor resource and overlay the time patterns for the Labor and Cutter resources, your overview should appear as shown next.

Create named views

In FactoryTalk Scheduler applications with a large number of resources, it is sometimes desirable to create different views of the Sequence Overview window or planning board for different users. Although our tutorial system is not large and can easily be viewed in its current format, let's assume that we would like to create several different views. First, we would like to retain the current view, with some minor changes, and create two new views (Fabrication and Assembly).

To begin, let's rearrange the current view (called the default Gantt view) so the order of the resources, which are shown at the left side of the view, follows the general sequence of use by the orders. We want the order of the resources (from top to bottom) to be Cutter, Bender, Machiner, Welder, Finisher, Subassembly Area 1, Subassembly Area 2, Assembly and Pack Area 1, Assembly and Pack Area 2, and Labor. You can move the position of the resources by placing your cursor on the selected resource name, click and hold, then move your cursor to just above another resources or shift patterns are displayed. If you rearrange your view, be sure to save your file in order to save the rearranged view. If you



use this procedure, your resulting Sequence Overview window, or the default Gantt view, should resemble the window shown next.

Now let's create a new named view called Fabrication, which will only show the Cutter, Bender, Machiner, Welder, and Finisher resources (in that order). You create a new view by selecting the **View > Named Views > Modify List** menu option, which will open the Named Views dialog shown below. Press the **Create** button and enter the view name, **Fabrication**, and click **OK**. FACTORYTALK SCHEDULER USER'S GUIDE

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Named Views	? ×
Default Gantt	Create Delete
<u>N</u> ame: Fabrication	-
OK Cancel	<u>H</u> elp

This results in a new view being created and assigned the name "Fabrication." Note that this is basically a copy of the default Gantt view. Now we need to close this dialog, recall the new view (**View > Named Views > Fabrication**), and modify that view. In this case, we need to remove the assembly areas, subassembly areas, and the labor resource, which is only used in the assembly and subassembly areas. Place your cursor on the first resource (Subassembly Area 1), right-click and select the **Hide** menu option. This will cause the selected resource to be removed from the current view. Repeat this for the remaining resources that you want to remove from the Fabrication view. The resulting view is shown below.



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If you accidentally hide a resource that should be visible, simply right-click in the resource area of the view and select the **Unhide** menu option to cause the Hidden Rows dialog to appear. Select the resource you want to add to the current view and click the **Unhide** button. This will display the resource in the current view. Once you have created your new Named View (Fabrication), you'll need to save the *fcs* file, which contains the information on the Named Views.

Having created the Fabrication view, you'll now want to create the Assembly view. You should start with the Default Gantt view, which you can recall by selecting the **View** > **Named Views** > **Default Gantt** menu option. When recalling this view, you might notice that your newly created view is also included as an option on the menu. Repeat the above process to create the new Assembly view. You can retain these settings by saving the *fcs* file.

Unallocate and reallocate orders



For now, we'll look at how you can generate a schedule manually. First, we'll clear all jobs from our planning board by using the **Sequence > Unallocate All Orders** menu option. This action places all the operations back into the Unallocated Jobs window. Click on this window or use

the **View > Unallocated Orders** menu option to bring the window to the front. Now locate the set of operations (four) that make up the order "Neck Post 1." Click on the first entry (actually, you can click on any of the four) to highlight it. Right-click and select the **Sequence > Forward** option, as shown. This places all four of the operations on the planning board.

Next, select the "SSD Blue 2" order and repeat the scheduling process. If you look at the planning board now, you will notice that, in addition to scheduling this order, FactoryTalk Scheduler also scheduled the "SSD Blue Finished Frame 1" order. This additional order was scheduled because Operation 10, Assembly and Pack SSD Blue, of the "SSD Blue 2" order requires an SSD Blue Finished Frame for each item in the order. The "SSD Blue 2" order is for nine, and there were only six component items in stock at the start of the planning horizon. Thus, FactoryTalk Scheduler searched the unallocated jobs to find an order that would produce the required component item and scheduled that order as well so that the final SSD Blue order could be completed. You could continue to build a schedule in this manner or, at any time, choose one of the automatic sequencing options to complete the scheduling process.

Manually edit a schedule

Once you develop a partial or complete schedule, you can also use the *drag-and-drop* feature to make individual changes in how and where operations are scheduled. To illustrate this feature, let's start with the schedule of the three orders just created. Before we start, it would be a good idea to save this schedule in case you need to revert to the basic schedule. Now, place your cursor on the "Cut Neck Post" operation, which is the only operation currently on the Cutter resource. While you click and hold, move your cursor over another resource. Note that when the operation is over an invalid resource, your cursor changes to the "No" symbol. If you move it back over the Cutter resource (or any valid resource), the cursor changes back to the normal cursor. Now move your cursor over an invalid resource and release the hold. The operation will be released and will move back to its original position on the Cutter resource.

Before we actually move the operation, it will be helpful to understand what FactoryTalk Scheduler allows. If you use the drag-and-drop feature to move operations, FactoryTalk Scheduler assumes that the operation is being moved to a valid place on the schedule. By valid, we mean that all required resources and stocks are available at that time and that you are not violating any sequencing or special constraints. When you drop the operation on a valid resource, it only checks to make sure that the primary resource is available. If the primary resource is in an off-shift state, it shifts the position of the operation to a location where the resource is available. If you drop the operation at a position where another operation is scheduled, it moves that operation to make room for the dropped operation (again, only considering the primary resource). Since only the primary resource is considered when using the drag-and-drop feature, it is helpful to know that you might violate a scheduling constraint. Although FactoryTalk Scheduler allows you to override these constraints, it also provides information about possible violations and gives you the ability to adjust the revised schedule so that it is valid.

View the Project Pane



Consequently, we recommend that you open the Project Pane before you start any drag-and-drop activity. Do this with the **View** > **Project Pane** menu option to display the Project Pane window at the left. Two tabs at the bottom of this window allow you to switch between the Performance Pane and the Log Pane. For now, select the Log Pane. The entries in your Project Pane should look like those shown here.

Now if you drag-and-drop an operation, FactoryTalk Scheduler will write a message to this log suggesting that you check the

resulting schedule. You can perform such a check using the **Adjust > Check Sequence** menu option. With the Project Pane open, select the first operation on the Cutter

resource—the "Cut Neck Post" operation. Move it to the right and note the change in the window. A plus "+" sign appears in front of the Warning entry. Expand this and you will see the message shown next.

Project	Pane	x
	Error Sequence Problem Materials Problem Pool Problem Warning Misc Depration was moved. You may want to validate the schedule Status Informative	
	reformance	

If you perform a check, **Adjust > Check Sequence**, it will tell you that Validation is required for one operation, and it suggests that you check the log messages for more details. If you check the log, it will tell you that the operation "Machine Neck Post" operation, Operation 20, is out of sequence (as shown below).



You can avoid the need to perform the check by selecting the **Adjust > Validate Op On Drop** menu option. This causes FactoryTalk Scheduler to check automatically for sequence constraints whenever you drag-and-drop an operation, and any problems will be written to the log. You can clear this log file at any time by selecting the **Edit > Clear Log** menu option. If you violate a sequence constraint and want FactoryTalk Scheduler to accept the position of the moved operation, you can select the **Adjust > Forward** menu option. This moves all affected operations to a position where the sequence constraints are valid. Note that none of these actions consider other constraints; e.g., materials, additional resources, or special constraints. If you have these other types of constraints, you can get information on their validity by selecting both the Adjust > Validate Op On Drop and the Adjust > Extended Validate On Drop menu options. This checks all constraints and reports any violations in the log file.

Evaluate a schedule

Once you generate a schedule, you might want to evaluate its quality. Before proceeding further, you might want to unallocate all jobs and use the **Sequence > Forward > Release Date** menu option to get back to our original schedule.

The quality of any given schedule is extremely dependent upon the objectives set by the planners and is often dependent on several measures. Thus, FactoryTalk Scheduler provides a number of different ways to measure each possible schedule—performance metrics, charts, schedule analyzer, and reports.

Performance metrics

Let's start at the most aggregate level and work our way down. If you are interested in the total schedule performance, based on average measures, you might want to look at the performance score card. You can view this score card by selecting the **Performance** > **Performance Metrics** menu option. This displays the performance scorecard window shown below, which provides general information on the current schedule related to jobs and resources. Although it provides general performance measures for the entire schedule, it does not provide detailed information on specific jobs or resources.

	Early	Ontime	Late	Incomplete
Absolute	4	46	20	0
Percentage	5.71	65.71	28.57	0.00
Job Comple	tion Data Total	Minimum	Average	Maximum
Early Time	5 days 02:24	1 day 02:13	1 day 06:36	1 day 10:15
Late Time	44 days 15:52	1 day 08:03	2 days 05:35	3 days 18:03
Setup Time	2 days 18:55	00 hours 12 mins	00 hours 57 mins	09 hours 08 mins
Tear Down	00 hours 00 mins	00 hours 00 mins	00 hours 00 mins	00 hours 00 mins
Lead Time	69 days 19:43	01 hours 54 mins	23 hours 56 mins	6 days 00:36
-Schedule		02/10/02 22:00 0	0/05/02 17:02	14 days 18:03

Orders are considered to be on time by comparing their order end dates/times to the order due date times. If the difference falls within the specified late- or early-tolerance limits, the orders are considered to be on time. These tolerance limits can be specified by selected the **Setup > Performance Parameters** menu option as shown below. The default values for Early and Late Tolerance are 24 hours. For this example, any order that is completed within 24 hours of its due date is considered to be on time. We'll talk about the Activate Order Filtering option found in this dialog in the next chapter.

Performance Parameters	? ×
Performance Parameters	
Early Tolerance (hrs): 24	
Late Tolerance (hrs): 24	1
☐ Activate Order Filtering	
IMPORTANT NOTE: Changing this value will cause the baseline to be set to the current schedule automatically!	
OK Cancel <u>H</u> elp	

Charts



The next level of detail can be viewed by selecting the **Performance > Charts** menu option. This opens the Project Pane window from which you can select items to view. There are four groups of data that can be viewed—resource, material, pooled resources, and waiting time. As an example, let's look at our Machiner utilization. Click on the eyeglasses symbol that is overlaid with a red X

directly to the left of the Machiner resource listing to display a chart of the Machiner utilization in the Charts window. When revealed, the X is removed from the eyeglass symbol. If you click again, the chart will be removed and the X is added to the symbol, indicating that the chart is hidden. You can also open several charts at the same time. By clicking on the name of the resource, you can bring that chart to the front for viewing. You can also move the charts so that several can be viewed at the same time, or you can resize them as you would any object in a Windows program.

.

Show Data ✓ Title Visible Hide	
View 🕨	Zoom Min
Bring To Top	Zoom Lo
Send To Bottom	Zoom Std
✓ Background	Zoom Hi
Сору	Zoom Max Fill Screen
	lcon

Holding your cursor over the chart will display the legend. In this case, the bars represent the idle, process, off, and setup (in that order). You also have several other options available. You can display these by pointing at the chart and right-clicking. This gives you the options shown, which include showing the data.

If you select the **Show Data** option, a Chart Data window is displayed showing the data that was used to develop the chart. The Chart Data window for our Machiner resource utilization chart is shown below.

Datas									
Data:		Time In State							
State		Process	Idle	Setup	Off Shift				
Process	3	21	27	1	51				
< _egend:					Þ				
∢ _egend: Item		Value	3		▶ Done				
∢ _egend: Item Title	Machiner	Value	3						
Item Title X Axis	Machiner	Value Utilization	•		<u>D</u> one Apply Legend				

You might question why your process utilization is so low. Part of the reason is that the utilization values shown are for the entire 19-day time period (February 9 to February 27). You can change the chart horizon by selecting the **View > Chart Horizon** menu option. If we change the chart horizon so that we only consider the second full work week, Monday,

Chart Horizon		? ×
Chart Horizon		
	[5-b 17 2002 12:00 AM - 1	
Start Date	Feb 17, 2003 12:00 AM	
End Date	Eeb 22, 2003 12:00 AM	
Endbalo	1 00 LL, 2000 12:001 MI	
OK.	Cancel <u>H</u> elp	

February 17 to midnight Saturday, February 22, we'll get a more representative utilization chart.

The new chart is shown at the right. When you change the chart horizon, it is applied to all resource, pooled, and waiting time charts. The charts for materials still use the entire planning horizon. This chart horizon will remain until you exit the current FactoryTalk Scheduler application. The next time you open the application, the chart horizon will be reset to the entire time horizon.





Charts for pooled resources, our labor pool, show the number of labor resources available during the scheduling period. Thus, if there are three workers on-shift and two are currently scheduled, the chart will display a value of 1.

The material charts display two values—the amount of material currently on hand and the amount of uncommitted material. The amount of uncommitted material takes into consideration any operations that have already been allocated material in the future. For example, if the on-hand material is currently at 100, but 75 of these have been allocated to an operation that will start the next day, a value of 25 would be displayed for the uncommitted material level.

The waiting-time charts display the total amount of work content waiting in front of the resource. This work content includes the total processing time for operations waiting for the resource, not including the processing time of the operation currently being processed. Thus, the plot takes the form of a step function reflecting the arrival of new operations (step up) and the start of processing of waiting operations (step down).

The performance metrics and charts are standard FactoryTalk Scheduler features and are the same for all applications. FactoryTalk Scheduler reports can be customized to each application. We provide a number of reports with our tutorial system that represent the typical information that is included in most applications. These include two activity-based costing reports, daily and weekly resource utilization, scheduled and unscheduled orders, material levels, order details, dispatch lists, and labor pool allocation. These reports were developed using Crystal Reports[®] software and can be viewed within FactoryTalk Scheduler using the Crystal Reports runtime software provided with FactoryTalk Scheduler. There are also comparable reports available for the configuration console.

Schedule Analyzer

The Schedule Analyzer provides the ability to examine the performance of a schedule at the order and operation level. You can open the Schedule Analyzer window by selecting the **Performance > Schedule Analyzer** menu option. The upper part of the window displays the order information and the lower part displays the operation information. When you open the Schedule Analyzer window, there will be two entries in the order section, Late Orders and On-time Orders. If you click on the plus symbol (+) in front of each entry, the status of each order will be displayed. The order information includes the order name, due date, scheduled date (or completed date), and difference. The difference column represents the difference between the scheduled or completion date and the due date. Thus, the late orders will have a negative difference and the on-time orders will have a positive difference.

The initial display sequence of the orders is based on the order name. You change this sequence by clicking on a column header. This will cause the order sequence with the categories late or on time to be displayed based on the entries in that column. For example, if you click on the due date column header, the order will be based on the earliest due date first. Clicking a second time on the due date column header will reverse the sequence. If you open the window, expand out the two initial entries, click on the difference column header, then highlight the order (Neck Post 2), your window should appear as follows.

•	
-	

Orders	Due Date		Scheduled Completion	Difference	Material		BOM Level
Handlebar 1	02/14/2003 2	3:00	02/13/2003 12:44	1 day 10:15	Handlebar		2
Handlebar 2	02/17/2003 2	3:00	02/17/2003 14:52	08 hours 07 mins	Handlebar		2
Handlebar 3	02/19/2003 2	3:00	02/18/2003 17:07	1 day 05:52	Handlebar		2
Handlebar Assembly 1	02/11/2003 2	3:00	02/11/2003 12:36	10 hours 23 mins	Handlebar	Assembly	1
Handlebar Assembly 2	02/13/2003 2	3:00	02/13/2003 12:36	10 hours 23 mins	Handlebar	Assembly	1
Handlebar Assembly 3	02/17/2003 2	3:00	02/17/2003 12:54	10 hours 05 mins	Handlebar	Assembly	1
Handlebar Assembly 4	02/18/2003 2	3:00	02/20/2003 07:03	-1 day -8:-3	Handlebar	Assembly	1
Handlebar Assembly 5	02/20/2003 2	3:00	02/21/2003 14:18	-15 hours -18 mins	Handlebar	Assembly	1
Neck Post 1	02/14/2003 2	3:00	02/13/2003 20:46	1 day 02:13	Neck Post		2
Neck Post 2	02/17/2003 2	3:00	02/19/2003 17:26	-1 day -18:-26	Neck Post		2
Neck Post 3	02/19/2003 2	3:00	02/21/2003 08:42	-1 day -9:-42	Neck Post		2
Seat Assembly 1	02/11/2003 2	3:00	02/11/2003 13:30	09 hours 30 mins	Seat Asser	nbly	1
Seat Assembly 2	02/13/2003 2	:3:00	02/13/2003 13:30	09 hours 30 mins	Seat Asser	nbly	1
Seat Assembly 3	02/17/2003 2	:3:00	02/17/2003 19:24	03 hours 35 mins	Seat Asser	nbly	1
Seat Assembly 4	02/18/2003 2	3:00	02/19/2003 17:19	-18 hours -19 mins	Seat Asser	nbly	1
Seat Assembly 5	02/20/2003 2	3:00	02/21/2003 20:48	-21 hours -48 mins	Seat Asser	nbly	1
Seat Post 1	02/17/2003 2	3:00	02/19/2003 10:49	-1 day -11:-49	Seat Post		2
Operations for Selected Order	r Op Number	Resource	Setup Start Date	Process Start Date	Teardown End Date	Release Date	Available Time
Cut Neck Post	10	Cutter	02/13/2003 19:06	02/13/2003 19:19	02/14/2003 11:07	02/12/2003 23:00)
Machine Neck Post	20	Machiner	02/17/2003 14:31	02/17/2003 15:06	02/18/2003 13:30	02/12/2003 23:00) 3 days 03:24
Bend Neck Post	30	Bender	02/18/2003 14:30	02/18/2003 14:46	02/19/2003 07:25	02/12/2003 23:00) 01 hours 00 mins
Finish Neck Post	40	Finisher	02/19/2003 08:25	02/19/2003 08:33	02/19/2003 17:26	02/12/2003 23:00) 01 hours 00 mins

Clicking on the Neck Post 2 order causes the operations of the order to be displayed in the operations section of the window. The initial sequence of the operations is based on the Op Number. You can re-sequence the order by clicking on any of the operation column headers. Now double-click on the second operation, Op Number 20, which will open the Operation Constraints window for that operation, shown below.

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Operation: Op Number: Quantity: Setup Start: Order End:	Machine Na 20 120.00 02/17/2003 02/19/2003	3 14:31 3 17:26			Resource: Order: Material Name: Process Start: Process End:	Machiner Neck Post 2 Neck Post 02/17/2003 15:06 02/18/2003 13:30
Hours Waiting for Primary: Preceding Operations:	19.40 Op Num:	Op Name: Cut Neck Post	Quantity: 120.00	Resource: Cutter	Resource Utilization (%): Setup Start: 02/13/2003 19:06	Machiner : 100.00 Teardown End: 5 02/14/2003 11:07
Subsequent Operations:	30 40	Bend Neck Post Finish Neck Post	120.00 120.00	Bender Finisher	02/18/2003 14-30 02/19/2003 08:25	0 02/19/2003 07:25 5 02/19/2003 17:26

This window provides additional information on the selected operation. The upper-left part of the window displays the basic operation information, while the upper-right part displays the basic order information. The **Attributes** button at the far right will open the same Attributes window that you can open by double-clicking on an operation in the Sequence Overview window. The center part of the window displays two additional values, hours waiting for the primary resource and resource utilization, which may be be useful in evaluating why the order is late. In our example, the operation was required to wait 19.4 hours for the Machiner resource to become available. Note that this wait time does not include any times that the Machiner resource was not available; e.g., off-shift time. The utilization of the Machiner resource (100%) indicates that the resource was busy during the entire wait time.

The prerequisite operations and subsequent operations are shown in the lower portion of the window. There are no material requirements for this operation, but Operation 10 appears in the prerequisite portion and Operations 30 and 40 appear in the subsequent operation portion.

The material and fixture constraints can be viewed using the Material Prerequisites and Fixtures tab.

Close the Operation Constraints window and scroll down the on-time orders until you find the SHP Red 6 order. Click on this order and then double-click on the single Operation 10 for this order. This operation requires additional resources (two Labor resources) and materials as shown below.

Schedule Analyzer Operation Constraints Mate	arial Prerequisites and Fixtures				
Operation: Op Number: Quantity: Setup Start: Order End: Hours Waiting for Phimay:	Assemble and Pack SHP Red 10 20.00 02/20/2003 08:27 02/20/2003 16:16 17.45		Resour Order: Materia Proces Proces Resour	ce: A S I Name: S s Start: 0 s End: 0 ce Utilization (%): A L	ssembly and Pack Area 1 HP Red 6 HP Red Bicycle 2/20/2003 08:52 2/20/2003 16:16 ssembly and Pack Area 1: 82:00 abo: : 94:30
Material Prerequisites:	Material: Handleba Assembly Handleba Assembly Peda and Chain Assembly SHP Red Finded Frame SHP Red Finahed Frame Wheels	Quantity: 17.00 3.00 20.00 1.00 19.00 11.00 9.00	Date Available: 02/17/2003 12:54 02/20/2003 07:03 02/17/2003 18:00 02/17/2003 18:24 02/20/2003 08:27 02/17/2003 21:52 02/17/2003 18:00 02/18/2003 18:00	Order: Handlebar Assembly 3 Handlebar Assembly 4 MATERIAL Seat Assembly 3 SHP Red Finished Fre SHP Red Finished Fre MATERIAL MATERIAL	Dperation: 3 10 10 10 20 20 20 ×
Fixtures:	Fixture:	Quantity:	Date Available:	Usage Type:	Phase:
				OK	Attributes Cancel Help

The Resource Utilizations show values of 82% for Assembly and Pack Area 1 and 84.3% for Labor. These values are calculated only for the time that the operation is waiting for the primary resource, the Assembly and Pack Area 1. In this case, that would be from the order release date (2/18/03 11:00 PM, see order attributes) to the Setup Start time. The order release date is used for this calculation because this is the first operation for this order. If the selected operation is not the first operation, it would use the Teardown End Time of the predecessor operation for this calculation. Also note that these values do not include any time when the resource was unavailable. Also recall that there are three labor resources available each day. This would imply that the operation might not have been scheduled earlier due to the unavailability of two labor resources. However, if you look at the Sequence overview for that time period, you will notice that although the Labor is highly utilized for that time period, there are actually two labor resources available starting at 7:03 on the day the operation is scheduled. Thus, the unavailability of labor is not the cause for the delayed start of the operation.

Now let's turn our attention to the Material Prerequisites. This section lists all the materials required and their availability. If the material is a manufactured component, it will also provide the order that produced it. For example, there are two listings for the material Wheels, a purchased material. A total of 20 wheels are required, 11 coming from a material delivery on February 13 and nine wheels from a delivery on February 14. Further examination shows that the SHP Red Finished Frame component produced by the SHP Red Finished Frame 4 order is not complete until February 20 at 8:27. This is the constraint that causes the SHP Red 6 order to be started and completed late.

FactoryTalk Scheduler reports

Before viewing selected reports, you should be aware that the data for a report is taken from the FactoryTalk Scheduler database. Thus, if you made changes to your schedule, you will want to save that schedule, using the File > Save All or File > Save Report Data menu options, before viewing reports. There are also several reports that require that specific data be updated before you save your schedule. This data is not automatically updated each time you save your file as it does not affect the schedule and is only used for certain reports.

The Material Levels report references a specific database table that is used only to store the material history for the span of the current schedule. If you do not update this information, your material report could be based on potentially inaccurate data.

Although there are no tutorial reports that reference waiting-time, resource utilization, or pooled-resource utilization data, if a report is included with your application, you need to update the database before you view the report. There are four options for saving the database. The first two options, **File > Save** and **File > Save As**, do not update the resource utilization, pooled resource, material, and waiting-time data that are often used in reports. The **File > FCS** only saves the current FCS file. The **File > Save Report Data** saves only the data mentioned above. The **File > Save All** option saves both the database and report data. Unless your database is extremely large and requires a long time to save, we recommend using the **File > Save All** option.

After updating the necessary database tables and saving your schedule file, you can view reports by selecting the **Database > Reports** menu option, which provides a list of available reports for the current application. We will briefly describe and show a few of these reports.

•

A section of the Scheduled Orders report showing the orders due on 2/11/03 is shown below. In the actual report, several different colors are used for the values in the completion date column. This allows the user to identify easily the late, on-time, and early orders.

2/11/2003

Order.	<u>Customer:</u>	Priority:	<u>Quantity:</u>	Release Date:	<u>Due Date:</u>	Complete Date:
Handlebar Assembly 1	MRP	2	75	2/10/03 11:00 pm	2/11/03_11:00 pm	2/11/03 12:36 pm
Seat Assembly 1	MRP	2	75	2/10/03 11:00 pm	2/11/03_11:00 pm	2/11/03 1:30 pm
SHP Blue 1	STU	1	11	2/10/03 11:00 pm	2/11/03_11:00 pm	2/11/03 5:06 pm
SHP Blue Finished Frame 1	MRP	2	24	2/10/03 11:00 pm	2/11/03 11:00 pm	2/11/03 3:40 pm
SHP Red Finished Frame 1	MRP	2	24	2/10/03 11:00 pm	2/11/03 11:00 pm	2/11/03 5:51 pm
SSD Red 1	STU	1	11	2/10/03 11:00 pm	2/11/03 11:00 pm	2/11/03 9:36 pm
SSD Red Finished Frame 1	MRP	2	24	2/10/03 11:00 pm	2/11/03_11:00 pm	2/11/03 9:40 pm

A section of a typical dispatch or work-to list for the Assembly and Pack Area 1 resource shows the orders scheduled for 2/13/03. The remainder of this report provides a list of operations scheduled, by day, at each resource in the system.

Date: 2/13/03						
<u>Order:</u>	<u>Customer:</u>	Operation:	<u>Quantity:</u>	<u>Setup</u> <u>Start Time:</u>	<u>Process</u> <u>Start Time:</u>	<u>Process</u> End Time:
SHP Blue 3	STU	10 Assemble and Pack SHP	Blue 4	12:36 pm	1:02 pm	2:31 pm
SHP Red 2	MNOP	10 Assemble and Pack SHP	Red 9	2:31 pm	2:57 pm	6:16 pm
SSD Blue 2	HIJ	10 Assemble and Pack SSC	Blue 16	6:16 pm	6:42 pm	8:37 am

The Material Level report provides information on the replenishment and depletion of each of the defined materials. The information for the SHP Frame material is shown below.

Material:	SHP Frame			
<u>Date / Time</u>	Order	<u>Replenish</u>	<u>Deplete</u>	<u>Material Level</u>
02/10 12:00AM	Starting Inventory	97		97
02/11 7:07AM	SHP Blue Finished Frame 1		24	73
02/11 10:57AM	SHP Red Finished Frame 1		24	49
02/13 2:58PM	SHP Frame 1	50		99
02/14 8:43AM	SHP Blue Finished Frame 2		24	75
02/14 12:33PM	SHP Red Finished Frame 2		24	51
02/17 2:58PM	SHP Red Finished Frame 3		24	27
02/17 4:31PM	SHP Frame 2	50		77
02/18 5:14PM	SHP Blue Finished Frame 3		24	53
02/19 5:33PM	SHP Red Finished Frame 4		24	29
02/20 1:04PM	SHP Blue Finished Frame 4		24	5

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Where desirable, the information in a report also can be displayed in a graphical format. For example, the Schedule Performance report, shown below, is displayed in a pie-chart format.



These examples represent some of the types of information that can be obtained using the Report option. However, you may want to get a more complete picture by looking at the rest of the reports included with the tutorial system.

Summary

This chapter gave you a quick glimpse of FactoryTalk Scheduler using the tutorial system as the application. We intentionally didn't try to cover all the features available in FactoryTalk Scheduler since many are standard Windows operating system features or are options that will become obvious when you try them. However, a few features that do require additional explanation are covered in the next chapter where we discuss how to perform "what-if" analysis using the FactoryTalk Scheduler system.



In Chapter 6, we covered the basic procedures for using the FactoryTalk Scheduler system. In this chapter, we will show you how to edit some of the underlying data and many of the features that will allow you to perform schedule analysis.

Comparing different schedules

Once you have generated a schedule, FactoryTalk Scheduler provides several ways to evaluate its quality. Most of these were discussed in the previous chapter: performance metrics, charts and graphs, Schedule Analyzer, and reports. Although these allow you to evaluate a single schedule, they do not allow for easy comparison between different schedules. In order to make such comparisons easier, FactoryTalk Scheduler includes a net change feature that allows for direct comparisons between two different schedules.

In most applications, this type of analysis would not be performed on a daily basis. Typically, it is performed for a new application and then revisited if conditions change; e.g., product mix change, new resources, etc. The idea is to determine which scheduling method(s) or rule(s) will provide the best solution and then use this method(s) or rule(s) on a daily basis. For our tutorial, let's assume that we have a new application and it's not clear what will provide the best results.

Before you begin an analysis, we recommend that you examine the set of orders to be scheduled to determine which orders need to be completed on time. Our tutorial system has a total of 70 orders, but only 33 of these orders are end items or customer orders. FactoryTalk Scheduler allows you to control which orders are included in the performance metrics by activating the order-filtering capability. You can activate this feature by using the **Setup > Performance Parameters** menu option, which will open the Performance Parameters dialog shown below. Checking the Activate Order Filtering option will cause FactoryTalk Scheduler to filter out unwanted orders when calculating performance metrics.

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Ρ	erformance Parameters							
	Performance Parameters							
	Early Tolerance (hrs): 16							
	Late Tolerance (hrs):							
	Activate Order Filtering							
	IMPORTANT NOTE: Changing this value will cause the baseline to be set to the current schedule automatically!							
	OK Cancel Help							

This filter option uses the data in the last auxiliary Boolean attribute field for orders to determine which orders are to be filtered out. You can check the values for our tutorial system by opening the Attributes window and going to the last field in the Order tab. An entry of Null, 0 (zero), or False means that the order will not be filtered out, or that it will be included in the performance metrics. An entry of 1 or True means that the order will not be included in the performance metrics.

In our tutorial system, we entered False for all orders that are end items—orders that have a bill of materials level code of zero. We entered True for all other orders. We then activated the order filter option. This means that our performance metrics will only include the 33 end item or customer orders.

Since we need our orders to be completed on time, we have also changed our early and late tolerance times. All our orders are due at 11 PM, so we changed our Early Tolerance time to 16 hours and our Late Tolerance time to zero hours, as shown above.

Forward scheduling

Let's start with the schedule we generated in the previous chapter using the **Sequence** > **Forward** > **By Release Date** menu option. We will assume this to be our base schedule case and will generate alternate schedules on the board to compare against it. Once we have our base case, we'll define it as our base by selecting the **Performance** > **Set As Baseline** menu option. This temporarily saves a set of performance measures for the current schedule. You can view these performance measures by selecting the **Performance** > **Baseline** Comparison menu option. The upper portion of the resulting Baseline Comparison window is shown below.

4	Baseline Compa	rison				
Γ	- Order Statistics	Baseline	Now	Percent Change	Difference	
L	Late	20	20	0.00%	0	
L	Early	4	4	0.00%	0	
L	Ontime	46	46	0.00%	0	Total Late Jobs Unchanged: 20
L	Incomplete	0	0	Undefined	0	
L	Average Late	2 days 05:35	2 days 05:35	0.00%		I otal Early Jobs Unchanged: 4
	Average Early	1 day 06:36	1 day 06:36	0.00%		Total Ontime Jobs Unchanged: 46

This portion of the Baseline Comparison provides summary performance measures, much like the Performance Metrics window. The number of Late, Early, On Time, and Incomplete orders are absolute measures. Note that the values for both the Baseline and Now schedule are the same. Thus, the lower the value, the better the schedule. The Average Late and Average Early provide the average time a late order is late and the average time an early order is early. There are six additional panels in the lower portion of this window, which are currently blank. This area will be used to show the detailed differences between two schedules once we are doing comparisons.

The Baseline Comparison window could be closed before starting the comparisons, but for now, let's leave it open. As we proceed, FactoryTalk Scheduler will automatically update the statistics in this window. Now select the **Sequence > Unallocate All Orders** menu option to clear the planning board. Note the changes in the Baseline Comparison window. Now let's try the **Sequence > Forward > By Due Date** menu option.

The statistics in the Baseline Comparison window now show the data for the schedule generated using due date, as well as additional statistics comparing this schedule to the base case schedule. The upper portion of the Baseline Comparison window is shown below.

- Order Statistics					
0100101010100	Baseline	Now	Percent Change	Difference	
Late	20	21	5.00%	1	1
Early	4	1	-75.00%	-3	
Ontime	46	48	4.35%	2	Total Late Jobs Unchanged: 16
Incomplete	0	0	Undefined	0	
Average Late	2 days 05:35	2 days 15:00	-17.55%	· ·	Total Early Jobs Unchanged: 1
Average Early	1 day 06:36	1 day 03:13	11.01%		Total Ontime Jobs Unchanged: 42

The data in the left column are the statistics for the base schedule (in this case, the schedule generated using the sequence forward by release date method). The data in the second column are for the new schedule (the schedule generated using the sequence forward by due date method). The data in the far right column show the absolute difference between the current schedule statistics and the base case schedule. The data in

the third column show the relative percent of change between the two schedules using the base schedule as the base for comparison. Using these measures, you can determine whether the current schedule is better than the base schedule.

In our example, it appears that the baseline schedule is better, based on the fact that we have one fewer late job. However, you might want more detailed information on the schedule changes before you make this judgment. This information is available in the six panels in the lower portion of the Baseline Comparison window, where you'll find information on the orders where changes have occurred. These panels are separated into three categories: Late in Baseline (the top two panels), Early in Baseline (the middle two panels), and Ontime in Baseline (the bottom two panels). The two Late in Baseline panels include: Now Early and Now Ontime. The two Early in Baseline panels include: Now Late and Now Ontime. The two Ontime in Baseline panels include: Now Late, and Now Early. The panel for the Ontime in Baseline, Now Late orders is shown below. It lists the order name, order due date, and the time difference between the current schedule and the base schedule for the jobs that were late in the base schedule and are now ontime in the new schedule.

- O Г	ntime in Baseline Now Late					
	Total: 4					
	Handlebar Assemb <u>l</u> SHP Frame 2 SSD Blue 6 SSD Frame 1	y 5 02/17/03 02/19/03 02/17/03	02/20/0 23:00 23:00 23:00	13 23:00 1 day 23: 11 hours 1 day 23:	2 days 28 08 mins 28	16:54 24 secs

Simulation scheduling

Now clear the planning board (unallocate all orders) and select the **Sequence > Simulate** menu option to schedule the orders using simulation. The rules used by the simulation to create this schedule are the defaults: Earliest End Time for the resource rule, Highest Priority for the lot or operation rule, and Schedule File Order for the tie break rule. Later we'll show you how to change these rules.

Checking the Baseline Comparison window will show 12 fewer late jobs (21 late jobs) from the previous schedule and 11 fewer than the original schedule. At this point, you might want to consider different simulation rules.

Simulation setup

The BizBikes tutorial database assumes the default simulation rules. However, there may be times when you will want to change these rules. There are two basic ways to change the simulation setup. The first method will result in temporary changes that are not saved to the database. Thus, they will be lost when you exit the FactoryTalk Scheduler session. This method is best used when you are exploring the effects of using different rules.

You can make these changes by selecting the **Setup** > **Simulation Rules** menu option. This opens the Set Simulation Rules window shown below. If you position and click your cursor on one of the rules, the down arrow appears at the right of the field. Clicking on this down arrow allows you to select a new simulation rule for the resource group. Remember that this is a temporary change, but it will allow you to test the effect of the new selection.

Resource Sets	Resource Rule	Lot Rule	Tie Break Rule	Timed Offse
Assembly and Pack Areas	Earliest End Time	Highest Priority	Highest Priority	0
Bend_DynSet	Earliest End Time	Highest Priority	Highest Priority	0
Cut_DynSet	Earliest End Time	Highest Priority	Highest Priority	0
Finish_DynSet	Earliest End Time	Highest Priority	Highest Priority	0
Machine_DynSet	Earliest End Time	Highest Priority	Highest Priority	0
Subassembly Areas	Earliest End Time	Highest Priority	Highest Priority	0
Weld_DynSet	Earliest End Time	Highest Priority	Highest Priority	0
•				

Let's change the Lot Rule to Earliest Due Date for all but the Machine and Bend work centers. Since these two work centers have sequence-dependent setups, we'll change the Lot Rule to Least Setup Time, the Tie Break Rule to Earliest Due Date, and the Timed Offset to four days, as shown next.

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Resource Sets	Resource Rule	Lot Rule	Tie Break Rule	Timed Offse
Assembly and Pack Areas	Earliest End Time	Earliest Due Date	Highest Priority	0
Bend_DynSet	Least Setup Time	Least Setup Time	Earliest Due Date	4
Cut_DynSet	Earliest End Time	Earliest Due Date	Highest Priority	0
Finish_DynSet	Earliest End Time	Earliest Due Date	Highest Priority	0
Machine_DynSet	Least Setup Time	Least Setup Time	Earliest Due Date	4
Subassembly Areas	Earliest End Time	Earliest Due Date	Highest Priority	0
Weld_DynSet	Earliest End Time	Earliest Due Date	Highest Priority	0
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Now if we develop a schedule using simulation, it will use these new rules. This results in a schedule with 11 late jobs—two more than for the default rules.

If you want to make the selection permanent, you can exit FactoryTalk Scheduler and edit the FDM Data.

Now let's retain the same base case and try other forms of scheduling as part of our analysis.

Backward scheduling

Another form of scheduling that will occasionally provide good results is backward scheduling. Using this type of methodology, we select an order and first schedule the last operation to end on its due date, or as close as possible. We then work our way backward through the order routing scheduling each operation as we proceed. This guarantees that any order that can be scheduled completely will not be late, and it will tend to minimize the work-in-progress. The idea is to generate a schedule that completes orders, as close to on time as possible, without having any late orders. The problem that often develops using this method is that it is not possible to schedule all orders in this manner because you would have had to start, and possibly complete, some operations for orders before the current time.

First, clear the planning board using the **Sequence > Unallocate All Orders** menu option. Now select the **Sequence > Backward > By Due Date** menu option. The baseline comparison indicates that we have 25 orders completed on time, 12 more than for the base case, but eight of the orders are incomplete or unscheduled. This implies that these orders can't be scheduled with the backward method because there is insufficient time to complete these orders. However, we can schedule these orders using the forward method. Now, use the **Sequence > Forward > By Release Date** menu option to schedule the remaining orders.

Reviewing the comparison indicates that we have reduced our number of late orders by 12 compared to our base case.

A closer inspection of our comparison shows that we have increased the lateness of our late jobs significantly. If determining the better schedule is your responsibility, you may have to take a closer look at the details of the late orders, which you can do easily by using the Schedule Analyzer. For now, let's continue our analysis.

Bottleneck scheduling

FactoryTalk Scheduler bottleneck scheduling is based on the concepts of the theory of constraints. It attempts to develop a schedule that emphasizes the use of the declared bottleneck resources. If you select the **Database > View** menu option, followed by the **Database > Open > Resources** menu option, you will be able to see that none of our resources have been checked as a bottleneck resource. Before we can use this method, we first need to determine if we have any resources that are truly bottlenecks.

One method for identifying bottlenecks is to examine the queue in front of each resource over time. We can easily do this by opening the Charts window and looking at the waiting time plots for each resource. With one exception, there is very little work waiting. The exception is the Assembly and Pack Area 1 resource and the Machiner, which has as much as 56 hours and 30 hours of work, respectively, waiting for the resource. Although this would tend to indicate that this is a bottleneck, which could be set as such, it would have very little impact on the resulting schedule. There are two reasons for this. The first reason is that the only orders that use the Assembly and Pack areas are the end product items, which have only one operation. Thus, the bottleneck concepts do not apply. In addition, there are two Assembly and Pack areas and the second area is not used. This is because the constraint or bottleneck is not the Assembly and Pack areas but is the availability of labor. Each operation at these areas requires two labor resources, and we have a labor pool of three. Thus, the second area will never be used.

Since the bottleneck concepts do not apply to additional resources, we need to consider a different approach. One possible alternative is to consider the impact of increasing our labor pool capacity to four. We'll do this next.

Adding pooled resources

The number of labor resources (an Adjustable Pooled resource) is defined by the time pattern attached to that resource. In order for us to change this value, we need to define a new time pattern with a capacity of four and attach it to our Labor resource. In Appendix D, we show how to use the time pattern editors. Included in the time patterns already

developed is a "2 by 5 Pool 4," which is what we need. If we attach this time pattern to our Labor resource, we can check our results using the **Sequence > Simulate** option. The comparison reveals that the number of late orders is now four. Using the backward method followed by the forward by release date option provides an increase in the number of late orders (eight) with all orders scheduled. Increasing the labor pool to five results in five late orders for Backward By Due Date and Forward By Release Date. The simulation yields four late orders.

Analysis summary

Throughout our analysis of schedule options, we have assumed that the primary objective was to reduce the number of late orders. We started with 20 late orders for our baseline case and reduced this number to four. In most scheduling environments, it is necessary to consider multiple performance measures when evaluating the quality of a schedule. For example, although we were able to reduce the number of late orders significantly, some of our methods reduced the number of late orders but caused the average late value of our late orders to be rather large.

So let's consider one additional performance measure for the schedules we evaluated: the largest difference between the due date and completion date for our latest end item (latest end order). Although this additional performance measure is not included in the Baseline Comparison, it can be obtained from the Schedule Analyzer. A summary of our eight main cases is given next.

- Case 1: Forward By Release Date
- Case 2: Forward By Due Date
- Case 3: Simulation (default rules)
- Case 4: Simulation (new rules)
- Case 5: Backward By Due Date & Forward By Release Date
- Case 6: Simulation (new rules Labor Pool 4)
- Case 7: Backward By Due Date & Forward By Release Date (Labor Pool 5)
- Case 8: Simulation (new rules Labor Pool 5)

	1	2	3	4	5	6	7	8
Late	20	21	9	11	8	4	5	4
Early	0	0	0	0	0	0	0	0
On Time	13	12	24	22	25	29	28	29
Avg. Late	1:16:01	1:16:07	2:04:28	1:19:58	7:06:53	2:21:05	2:08:30	2:20:56
Latest End Order	3:18:03	2:33:55	4:13:54	3:15:58	10:14:21	3:13:13	3:15:05	3:12:49

One might conclude that Case 8 provides the best results. It also yields one of the better values for the latest end order. You might note that Case 6 also had only four late jobs and about the same value for the latest end order time. Since this option requires one fewer labor resource, you might want to consider it over Case 8. Of course, Cases 6, 7, and 8 assumed you could increase the labor pool. If this were not feasible, you would need to consider the first five options.

The general objective of this exercise was to provide an example of how you can use the various scheduling options to generate alternate schedules and compare them to a baseline case. This type of analysis is rarely performed on a daily basis. Instead it would be performed on a periodic basis, once every one or two months, to provide assurance that you are currently using the best scheduling option. It was also the intent to illustrate that there are occasions where you must dig deeper into the schedule performance in order to determine which option is best.

Additional FactoryTalk Scheduler options

At any time during our scheduling analysis, we could have reset our base case. This does not save the schedule; it only saves the summary statistics that are used for comparisons. In our analysis, it would have been easy to recreate the schedule that we wanted because we were removing all orders from the planning board and generating each new schedule using the standard sequencing options. In a real-world application, it could be very difficult to recreate the schedule that was used for the base case. It is most likely that you would have significantly more resources and orders on the planning board. If you artificially moved the current timeline before unallocating or used the drag-and-drop features or any other methods that would require a specific set of actions to recreate the schedule, you might want to save the base case before performing more analysis. You can save this base case in the normal manner using the **File > Save**, **File > Save As**, or **File > Save All** menu options. If you want to save the base case under a different name, there are methods available to create backups of your database, but they are not part of the FactoryTalk Scheduler software.

A normal application implementation would include the integration of FactoryTalk Scheduler with other data sources; i.e., ERP system and shop-floor status system. Once this integration has been completed, it provides the ability to update automatically the shop and order status. It also provides the ability to add new products and routings.

Periodically, resources become unavailable for short periods of time. This unavailability may be due to a breakdown, preventive maintenance, holidays, etc. If these occur on a regularly scheduled basis, you might want to incorporate them into the shift patterns. However, most of these events are largely unpredictable. Others, such as preventive maintenance, are often scheduled to occur only after you know what work is scheduled for an individual resource. We refer to these types of events as calendar exceptions. There are two distinct types: individual and global. Examples of individual calendar exceptions

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would be the scheduling of a preventive maintenance activity or a breakdown, which only applies to one resource. Global calendar exceptions are typically used for holidays or factory shutdowns and are intended to affect the entire system. Both of these exceptions can be added using the Exceptions Editor (see Appendix D).



- Activity Area—a generic term for sites, areas, or lines within a production enterprise. An enterprise may contain one or more sites, which in turn may contain one or more areas, which may be comprised of one or more lines, which may have one or more work cells. A work cell may belong to an activity area at any level in this hierarchy. Statistics are automatically rolled-up through the activity area hierarchy.
- Activity-based Costing (ABC)—a costing method that assigns the cost of resources to the production lots that utilized those resources.
- Additional Resources—resources in addition to the primary resource that are held during one or more phases during an operation.
- **Area**—a physical, geographical, or logical grouping of lines and/or work cells within a site. A geographical location (e.g., Building 2) and main production capability (e.g., Electronic Assembly) usually identifies areas.
- Assembly Operation—an operation where two or more production lots are combined. Assembly operations are modeled using intermediate materials or by merging parallel flows in a process plan.
- Available To Promise—an approach that promises future orders based on uncommitted inventory as projected by the master production schedule (MPS). This method is based on the assumption of fixed lead times and infinite capacity.
- **Bad Order**—one that was completed but violated one or more operation constraints during the production process.
- **Bill of Materials (BOM)**—The raw materials, component parts, or subassemblies required to manufacture an end item.
- **Buy Lead Time**—represents the estimated time delay (in days) between a purchase request for material and the time that purchase order actually arrives in the system and increases the material on-hand (e.g., the shipping time).
- **Calendar Exception**—an override of a time pattern for a specific time interval. Exceptions are typically used to represent holidays, planned maintenance, temporary schedule changes, and breakdowns.
- **Calendar State**—a state that may be used in defining work shifts for one or more resources. A calendar state defines a resource efficiency or capacity, along with color and pattern attributes for displaying the state in the Gantt chart. For example, shift states *Available* and *Unavailable* could define resource capacities of 1.0 and 0.0, respectively.

- **Composite Time Pattern**—a base pattern with exceptions that is used to define a shift pattern for a resource.
- **Conveyor**—a continuous transfer device that moves production lots from one station to the next. A transfer via a conveyor requires a free space on the conveyor. Conveyors come in many different types including belt, roller, chain, and bucket. Conveyors can have both accumulating and non-accumulating exit points.
- **Earliness**—the positive difference between the completion time and the due date of an early order.
- Early Order-one that is completed before its due date.
- Enterprise Resource Planning (ERP)—an accounting-oriented information system for identifying and planning the enterprise-wide resources and materials needed to take, make, ship, and track customer orders.
- **Entity**—a generic item that moves through the model. A generic entity has no direct connection to manufacturing and cannot be processed through a work cell. The production lot is a special type of entity that is associated with a manufacturing order and carries manufacturing-specific data. A production lot is the only type of entity that may be processed through a work cell.
- **Good Order**—one that was completed without violating any operation constraints during the production process (e.g., MakeSpan constraint).
- Job Segment—a specific job step in a manufacturing process.
- Line—a collection of one or more work cells that are combined to perform work. The geographical location (e.g., West Side) and main production capability (e.g., Bottling) usually identify sites.
- **Lot Splitting**—the process of dividing a production lot into two or more sub-lots that can be processed on separate machines, usually for the purpose of expediting an order.
- **Make Lead Time**—represents the estimated time to manufacture an order of material, assuming all BOM requirements are met (e.g., the assembly time).
- **Make-to-Order**—a production environment where a product is made only after the receipt of a customer order.
- Make-to-Stock—a production environment where products are made and stored in inventory in advance of the receipt of customer orders.
- Manufacturing Order—a business transaction that defines a requirement to produce a quantity of a specific product by a specified time. One or more manufacturing orders may be associated with a given customer order. A manufacturing order also may be

generated to produce components or subassemblies to-stock that are required for manufacturing orders for finished products.

- **Manufacturing Order Plan**—an actual plan for manufacturing an order in the facility. The manufacturing order plan is comprised of a collection of operations that define the detailed work for operations to be performed, as well as actual data on operations that have been completed. The manufacturing order plan is an order-specific and expanded version of the process plan for a product.
- **Manufacturing Resource Planning (MRPII)**—an extension of MRP and consists of a set of methods for effectively planning the requirements for all resources and materials for manufacturing.
- Master Production Schedule (MPS)—the anticipated build schedule for a company, expressed in specific configurations, quantities, and dates. The MPS data drive the MRP system.
- Material—a changeable quantity of stock that represents finished product, raw material, component parts, consumables, subassemblies, etc., that can be consumed or produced at each phase of an operation. Material has an associated stock level that increases and decreases with consumption and production and also increases with the external purchase of material. Material can be manufactured or purchased; material that can be manufactured has an associated process plan that defines the job segments required to produce the material.
- Material Actions—defined within the segment data for an operation, it specifies the consumption or production of material at specific phases.
- Material Arrivals-scheduled external arrivals of additional material.
- Material Requirements Planning (MRP)—a set of techniques that uses bill of material data, inventory data, and the master production schedule to calculate requirements for material and to generate manufacturing orders for release to the factory.
- Net Requirements—calculated by an MRP system as the net requirements for material, parts, or assemblies and is computed as a result of combining gross requirements and allocations against inventory on hand, scheduled receipts, and safety stock. Net requirements are then consolidated into planned orders based on lead times and economic order quantities.
- Netting-the process within MRP of calculating net requirements.
- **Operation**—work performed on a production lot at a work cell. An operation is defined by an *order-specific* job step record that is created by making a copy of the information in the job segment from the product's process plan and augmenting it with additional parameters to maintain actual schedule information.

- **Operation Constraint**—a restriction placed on the duration, start, or end time of an operation. Operation constraints include *Maximum Span*, which limits the maximum operation duration, and *Minimum End Offset*, which limits the offset time between the end of the previous operation and the start of this operation.
- **Operation Parameter**—a named value associated with a manufacturing operation. Operation parameters may be used to determine the phase times of an operation or referenced by lot selection logic to decide which lot to process next. The operation parameter values of a production lot may be defined at the order, product, or job segment data levels.
- **Operation Phase Times**—the times assigned to each phase of an operation. Each phase time has both a *Deterministic Plan Time* and a *Random Simulation Time*. The Deterministic Plan Time is used by FactoryTalk Scheduler to generate a deterministic schedule for the facility.
- **Operation Phases**—the individual phases that make up an operation. These phases include setup, processing, and teardown. Each phase has its own duration and can have specific resource and material actions.
- **Operation Planned Station**—a parameter of an operation that defines the next station in the process plan for this order. If parallel operations follow this operation, then this parameter returns the first of these stations.
- **Operation Priority**—a parameter of a manufacturing order or operation. The priority can be used in lot selection logic to decide which lot to process next. The value of this parameter is always defined at the order level, but may also be redefined at the job data segment level.
- **Operation Sequence Number**—a number assigned to each operation that may be used to establish the order and sequence of operations. A sequence number is made up of a base number, with one or more sub-thread numbers appended following a dot (.). For example, 30.1.5 has a base sequence number of 30, sub-thread of 1, and second level sub-thread of 5.
- **Order Due Date**—a parameter of a manufacturing order that establishes the date/time when the order is due. The value of this parameter is defined at the order level.
- **Order Earliest Start Date**—a parameter of a manufacturing order that establishes the earliest date/time when the order can start its first operation. The value of this parameter is defined at the order level.
- **Pegging**—the process within MRP of associating with a given item the sources of its gross requirements and/or allocations. *Soft pegging* is a temporary association that may be changed when rescheduling occurs. *Hard pegging* is a permanent association that cannot be changed by rescheduling.

- **Primary Resource**—a resource that is specified as a primary resource at a work cell. Every work cell has a primary resource that is always seized and held for the duration of an operation. The primary resource may also be carried across multiple operations.
- **Process Plan**—a generic plan for manufacturing material in a facility. It is associated with a material and is independent of any specific order for the material. It is comprised of a collection of job segments that defines the sequence and ordering of work required to manufacture the material. A process plan may define a simple flow through a linear sequence of job segments, or it may be a complex flow involving multiple and parallel job segments that are combined at an assembly job step.
- **Process Segment Data**—segment data for a job segment that is product independent. For example, the same machine attendant may be used at a work cell, independent of the material/product being produced. In this case, the machine attendant can be specified as process segment data. Segment data may include phase times, resource requirements, material actions, and constraints.
- Processing Phase-the second of three phases in an operation.
- **Product Segment Data**—segment data for a job segment that is product dependent. For example, the setup time on a machine may change from one job to the next; and in this case, the setup time is product segment data. Segment data may include phase times, resource requirements, material actions, and constraints.
- Production Lot—a unit of work that is associated with a manufacturing order. In some cases, multiple production lots are associated with a manufacturing order. Production lots move from operation to operation and may be combined at assembly operations. A production lot can be a single item or a batch of items that move together through the facility. A production lot may correspond to subassemblies and component parts that are produced to inventory or feed assembly operations or may correspond to final product.
- **Reorder Policy**—a policy for replenishing the supply of a material when the unallocated quantity of that material falls below a certain level (referred to as the Reorder Point).
- **Resource**—a generic term for equipment, labor, fixtures, racks, tools, and other items that may restrict the flow of work at a work cell.
- **Resource Busy Cost**—the cost accrued per unit time for an allocated resource. This cost accumulates during the setup, processing, and teardown phases of an operation. This cost value is used to compute activity-based costing (ABC) for the production lots.
- **Resource Capacity**—specifies the number of identical and interchangeable units of a pooled resource. The resource capacity can be specified either as a number or it can follow a predefined schedule.

- **Resource Efficiency**—alters the rate at which work is performed using a resource. The actual work duration is the planned work duration divided by the efficiency. Hence, values greater than 1 shorten the time and values less than 1 lengthen the time. An efficiency of 0 makes the resource unavailable.
- **Resource Idle Cost**—the cost accrued per unit time for an unallocated resource. This cost value is used to compute activity-based costing (ABC) for the production lots.
- **Resource Set**—a group of resources from which a selection can be made. A resource may be included in more than one group.
- **Route**—an unconstrained transfer of production lots from one station to the next. There are no devices (such as a limited number of carts) that restrict the transfer. The route activity requires a specified time to perform.
- **Scheduling**—the process of creating a schedule. Schedules that consider the constraints of material and resources are called *finite-capacity schedules*; those that do not are called *infinite-capacity schedules*. Shop-floor schedules are typically finite-capacity schedules.
- Segment Data—a set of data defining the phase times, additional resources, material, and constraints required to carry out a job segment. Product segment data is related to a specific product or material, whereas process segment data is product independent.
- Selection Logic—a collection of decision rules for deciding which production lot to process next and which resource to use for processing. The selection logic may include a lot selection rule, a resource selection rule, and a tie-breaking rule.
- **Sequencing**—the process of determining the order in which a manufacturing facility processes jobs in order to achieve certain objectives. Sequencing can be applied to entire jobs or to individual operations.
- Setup Phase—the first of three phases in an operation. The setup time can be a constant or can be sequence dependent.
- Site—a physical, geographical, or logical grouping of areas, lines, and work cells within an enterprise. A geographical location (e.g., Dallas) and main production capability (Brake Pads) usually identify sites.
- Station—a physical location within a work cell where production lots are transferred into and out of the work cell.
- **Tardiness**—the positive difference between the completion time and the due date of a tardy order.
- Tardy Order—one that is completed after its due date.

Teardown Phase-the last of three phases in an operation.
- **Time Pattern**—a collection of calendar values, shift states, or other time patterns that have been assigned to specific blocks of time. For example, a time pattern named *First Shift* might define time blocks 8 to 12 as *Available*, 12 to 13 as *Unavailable*, and 13 to 17 as *Available*. Time patterns are building blocks that are used to construct complete work schedules for a resource.
- **Transfer**—the movement of a production lot from one work cell station to the next work cell station. Transfers between stations can be performed using conveyors, transporters, or simple routes.
- **Transporter**—a discrete transfer device that moves production lots from one station to the next. A transfer via a transporter requires an available transporter device. Transporters come in many different types including carts, cranes, forklift trucks, and AGVs. Transporters can operate in both *free-path* and *fixed-path* modes.
- Utilization—the fraction of time that a resource is being used by a production lot.
- Work Cell—a location and/or group of equipment used to perform work in a manufacturing process. The operations in a manufacturing process are performed at work cells. A work cell typically is a physical location of a primary resource (e.g., a machine); however, it may also represent a logical grouping of primary resources from which a selection is made. A main production capability (e.g., Inspection) and designated location number (e.g., #1) usually identify a work cell.
- Work-in-Process (WIP)—the total number of production lots in a work cell, area, line, site, or enterprise.

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SHP RED BICYCLE

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble and Pack SHP Red	Assembly and Pack	0.43	0.37	Labor (2)	Components required: SHP Red Finished Frame Pedal and Chain Assembly Handlebar Assembly Wheels Derailleur Assembly Seat Assembly Brakes



SHP BLUE BICYCLE

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble and Pack SHP Blue	Assembly and Pack	0.43	0.37	Labor (2)	Components required: SHP Blue Finished Frame Pedal and Chain Assembly Handlebar Assembly Wheels Derailleur Assembly Seat Assembly Brakes



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SSD RED BICYCLE

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble and Pack SSD Red	Assembly and Pack	0.37	0.43	Labor (2)	Components required: SSD Red Finished Frame Pedal and Chain Assembly Handlebar Assembly Wheels Derailleur Assembly Seat Assembly Brakes



SSD BLUE BICYCLE

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble and Pack SSD Blue	Assembly and Pack	0.37	0.43	Labor (2)	Components required: SSD Blue Finished Frame Pedal and Chain Assembly Handlebar Assembly Wheels Derailleur Assembly Seat Assembly Brakes



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SHP RED FINISHED FRAME

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Finish SHP Red Frame	Finish	0.11	0.155		SHP Frame required
20	Assemble SHP Red Frame	Subassembly	0.19	0.083	Labor (1)	Place in inventory



SHP BLUE FINISHED FRAME

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Finish SHP Blue Frame	Finish	0.11	0.155		SHP Frame required
20	Assemble SHP Blue Frame	Subassembly	0.19	0.083	Labor (1)	Place in inventory



SSD RED FINISHED FRAME

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Finish SSD Red Frame	Finish	0.11	0.155		SSD Frame required
20	Assemble SSD Red Frame	Subassembly	0.19	0.083	Labor (1)	Place in inventory



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SSD BLUE FINISHED FRAME

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Finish SSD Blue Frame	Finish	0.11	0.155		SSD Frame required
20	Assemble SSD Blue Frame	Subassembly	0.19	0.083	Labor (1)	Place in inventory



SHP FRAME

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Cut SHP Frame Tubing	Cut	0.36	0.12		
20	Bend SHP Frame Tubing	Bend	BM	0.154		
30	Machine SHP Frame Tubing	Machine	MM	0.211		
40	Weld SHP Frame	Weld	WD	0.234		Place in inventory



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SSD FRAME

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Cut SSD Frame Tubing	Cut	0.32	0.12		
20	Bend SSD Frame Tubing	Bend	BM	0.154		
30	Machine SSD Frame Tubing	Machine	MM	0.211		
40	Weld SSD Frame	Weld	WD	0.234		Place in inventory



HANDLEBAR ASSEMBLY

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble Handlebar	Subassembly	0.21	0.072	Labor (1)	Handlebar and Neck Post required Place in inventory



HANDLEBAR

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Cut Handlebar Tubing	Cut	0.16	0.055		
20	Bend Handlebar Tubing	Bend	BM	0.043		
30	Finish Handlebar	Finish	0.14	0.088		Place in inventory



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NECK POST

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Cut Neck Post	Cut	0.21	0.065		
20	Machine Neck Post	Machine	MM	0.120		
30	Bend Neck Post	Bend	BM	0.072		
40	Finish Neck Post	Finish	0.14	0.074		Place in inventory



SEAT ASSEMBLY

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Assemble Seat and Post	Subassembly	0.20	0.084	Labor (1)	Seat and Seat Post required Place in inventory



SEAT POST

Seq #	Operation	Work Cell	Setup Time	Process Time	Additional Resources	Notes
10	Cut Seat Post	Cut	0.17	0.068		
20	Machine Seat Post	Machine	MM	0.130		Place in inventory





SHP Red Bicycle

LEVEL: 0	LEAD	TIME:	1							
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req			15	9	8	12	17	20	9	7
Sched			15	9	8	12	17	20	9	7
On Hand (0)										
Order Rel		15	9	8	12	17	20	9	7	

SHP Blue Bicycle

LEVEL: 0	LEAD	Тіме:	1							
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req		11	6	4	14	11	16	8	6	15
Sched		11	6	4	14	11	16	8	6	15
On Hand (0)										
Order Rel	11	6	4	14	11	16	8	6	15	

SSD Red Bicycle

LEVEL: 0	LEAD	Тіме:	1							
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req		11	9	8	14		12	7	6	12
Sched		11	9	8	14		12	7	6	12
On Hand (0)										
Order Rel	11	9	8	14		12	7	6	12	

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SSD Blue Bicycle

LEVEL: 0	LEAD	Тіме:	1							
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req			5	16	9	12	8	13	18	15
Sched			5	16	9	12	8	13	18	15
On Hand (0)										
Order Rel		5	16	9	12	8	13	18	15	

SHP Red Finished Frame

LEVEL: 1	LEAD	TIME:	1	LOT S	SIZE: 2	24				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req		15	9	8	12	17	20	9	7	
Sched		24			24	24	24			
On Hand (8)	8	17	8		12	19	23	14	7	7
Order Rel	24			24	24	24				

SHP Blue Finished Frame

LEVEL: 1	LEAD	TIME:	1	LOT S	SIZE: 2	24					
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21	
Gross Req	11	6	4	14	11	16	8	6	15		
Sched		24			24		24		24		
On Hand (16)	5	23	19	5	18	2	18	12	21	21	
Order Rel	24			24		24		24			

•

SSD Red Finished Frame

LEVEL: 1	LEAD	TIME:	1	LOT S	SIZE: 2	24				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	11	9	8	14		12	7	6	12	
Sched		24		24				24		
On Hand (17)	6	21	13	23	23	11	4	22	10	10
Order Rel	24		24				24			

SSD Blue Finished Frame

LEVEL: 1	LEAD	Тіме:	1	LOT S	SIZE: 2	4				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req		5	16	9	12	8	13	18	15	
Sched			24		24		24	24		
On Hand (6)	6	1	9		12	4	15	21	6	6
Order Rel		24		24		24	24			

Handlebar Assembly

LEVEL: 1	LEAD	TIME:	1	LOT S	SIZE: 7	'5				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	22	35	37	45	35	53	48	39	49	
Sched		75		75		75	75		75	
On Hand (27)	5	45	8	38	3	25	52	13	39	39
Order Rel	75		75		75	75		75		

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Seat Assembly

LEVEL: 1	LEAD	TIME:	1	LOT S	SIZE: 7	5				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	22	35	37	45	35	53	48	39	49	
Sched		75		75		75	75		75	
On Hand (36)	14	54	17	47	12	34	61	22	48	48
Order Rel	75		75		75	75		75		

Pedal and Chain Assembly

LEVEL: 1	LEAD	Тіме:	3	LOT S	SIZE: 6	0				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	22	35	37	45	35	53	48	39	49	
Sched	60		60	60		60	60		60	
On Hand	53	18	41	56	21	28	40	1	12	12
Order Rel	60		60	60		60				

Brakes

LEVEL: 1	LEAD	Тіме:	2	LOT S	SIZE: 7	' 5				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	22	35	37	45	35	53	48	39	49	
Sched		75		75		75		75	75	
On Hand (50)	28	68	31	61	26	48		36	62	62
Order Rel	75	75		75		75	75			

Wheels

LEVEL: 1	LEAD	TIME:	3	LOT S	Size: 4	8				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	22	35	37	45	35	53	48	39	49	
Sched		48		48	48	48	48	48	48	
On Hand (540	32	45	8	11	24	19	19	28	27	27
Order Rel	48	48	48	48	48	48				

Derailleur Assembly

LEVEL: 1	LEAD	Тіме:	4	LOT S	SIZE: 6	0				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	22	35	37	45	35	53	48	39	49	
Sched		60		60		60	60	60	60	
On Hand (54)	32	57	20	35		7	19	40	51	51
Order Rel		60	60	60	60					

Seat Post

LEVEL: 2	LEAD	Тіме:	3	LOT S	SIZE: 1	00				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	75		75		75	75		75		
Sched	100		100	77		100		100		
On Hand (27)	52	52	77		2	27	27	52	52	52
Order Rel			100		100					

.

Handlebar

LEVEL: 2	LEAD	TIME:	3	LOT S	SIZE: 1	00				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	75		75		75	75		75		
Sched	100				100	100		100		
On Hand (55)	80	80	5	5	30	55	55	80	80	80
Order Rel		100	100		100					

Neck Post

LEVEL: 2 LEAD TIME: 3 LOT SIZE: 60

Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	75		75		75	75		75		
Sched	60		60		60	120		60		
On Hand (58)	43	43	28	28	13	58	58	43	43	43
Order Rel		60	120		60					

SHP Frame

LEVEL: 2 LEAD TIME: 4 LOT SIZE: 50

Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	48			48	24	48		24		
Sched	50				50	50				
On Hand (47)	49	49	49	1	27	29	29	5	5	5
Order Rel	50	50								

•

SSD Frame

LEVEL: 2	LEAD	TIME:	4	LOT S	SIZE: 5	50				
Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	24	24	24	24		24	48			
Sched	50		50			50	50			
On Hand (4)	30	6	32	8	8	34	36	36	36	36
Order Rel		50	50							

Seat

LEVEL: 2 LEAD TIME: 2 LOT SIZE: 100

Period	2/10	2/11	2/12	2/13	2/14	2/17	2/18	2/19	2/20	2/21
Gross Req	75		75		75	75		75		
Sched	100				100	100		100		
On Hand (54)	79	79	4	4	29	54	54	79	79	79
Order Rel			100	100		100				

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In this appendix, we'll introduce the three available time pattern editors and show you how to use them in the context of FactoryTalk Scheduler.

Time pattern types

Time patterns are an important part of the FactoryTalk Scheduler application as they determine the availability—and in some cases, the efficiency—of your constraining resources. Each resource in your application will have two time patterns: capacity and efficiency.

The capacity time pattern defines the capacity, or the quantity available, over time. For Singular, Simultaneous, or Infinite resources, the capacity time pattern can only have values of zero (for unavailable times) or one (for available times). If a capacity value greater than one is entered for these resources, FactoryTalk Scheduler will default the value to one. The capacity value for an Adjustable Pooled resource can take on any value, including values with fractions (e.g., 3.5). If you do not develop you own time patterns, FactoryTalk Scheduler will automatically assign a default capacity time pattern. Typically, this is a pattern with a capacity of one available 24 hours a day, seven days a week.

The efficiency time pattern defines the efficiency or rate at which the resource processes operations. The default efficiency time pattern is typically a value of 1.0 (100%) over the entire time span, 24 hours a day, seven days a week. If you want a resource to process at different rates (e.g., a slower rate during the second shift), you would need to create and attach an efficiency time pattern with the different rates. For example, if you wanted a machine to process 10% slower, you would enter an efficiency rate of 0.9 (90%). The 10% slower rate is expressed as 90% as the efficiency factor is divided into the processing time to obtain the actual processing time.

When FactoryTalk Scheduler loads your application, it will first assign the efficiency time pattern to a resource. It will then overlay the capacity time pattern on the efficiency time pattern. To illustrate the results, let's assume that you have an efficiency time pattern that has a value of 1.0 for the first 12 hours, and a value of 0.9 for the remaining 12 hours in each day. This implies that your resource processes at 100% for the first 12 hours and at a 10% slower rate for the remaining 12 hours. Let's also assume your capacity schedule has unavailable (0 capacity) for the first 7 hours, available (capacity of 1) for the next 8 hours and unavailable for the last 9 hours. The composite time pattern would have the resource unavailable for the first 7 hours (capacity of 0). Even though the efficiency is 1.0, the machine is unavailable during that time. During the next 5 hours, the machine would be available and processing at a 100% rate (capacity of 1 and efficiency of 1.0). For the next

3 hours, the machine would be available and processing at a 90% rate (capacity of 1 and efficiency of 0.9). For the last 9 hours, the machine would be unavailable (capacity of 0).

Developing a time pattern

New Folder New Time Pattern Rename
Duplicate Delete

We'll lead you through the development of time patterns using those included with the tutorial systems. Let's start with the capacity time pattern for our Singular resources. First you need to select the **Database > Time Pattern > Time Pattern Editor** menu option. Under the Time Pattern section of the Time Pattern Editor window, you should have the following two folders, BizBikes 5 and Sample

Time Patterns. The time patterns in the BizBikes 5 folder are used in the BizBikes example. The time patterns in the Sample Time Patterns folder are used as illustrations in the Help topics. You may also have additional time patterns in your application, but we'll only deal with these five. If you want to develop a new time pattern, you would place your cursor on one of the entries in the Time Pattern section and right-click. The menu (shown at the left) will appear, from which you would select the New Time Pattern menu option.

You might note that the Delete menu option is grayed out if you selected one of our included patterns. This is because they are currently attached to the resources in our model. If you unattached one of these time patterns from all resources to which it is currently attached, this menu option would become available.

For now you just need to click on the **Shift 1** time pattern, which will cause the right portion of the window to display its properties, as shown below.

T: D.U.				
Time Patterns				X
<u>File Edit V</u> iew				
Time Patterns:	Time Pattern Type:	Time <u>Spans:</u>		🔽 Lock Times
🔞 BizBikes 5	Capacity 💌	Value	Start	End
2 By 5 Machine	, Default Value Type:	On Shift	0:00	8:00
2 By 5 Pool 3	State 🔻			
2 By 5 Pool 4	Default Value:	L		
2 By 5 Pool 5	Unavailable 🔻			
	Duration:			
Sample Time Patterns	8h			
Sample Labor Work Weel	Scale Factor	L		
Sample Preventive Mainte	1			
Sample Shift 1	·			
Sample Shift 2				
🚽 🦽 Sample Shift 3				
🚽 🔂 Sample Shift 4	2.00			· • •
🚽 🚽 Sample Shift 5	1 50			▶
🚽 👌 Sample Week 5 Days	1.50			+
Sample Week 7 Days	1.00-			-
	0.50-			•
• •	0.00	1 1	1/1/1995 4:00	1/1/1995 8:00
	1/1/10000.000			
			<u>O</u> K <u>C</u> a	ancel <u>H</u> elp
		_		

Now we'll show you how to develop this time pattern under a different name. To do this, right-click in the Time Pattern section and select the New Folder option. When the folder appears, change its name to **My Patterns**. Next click on the new folder followed by a right-click and select the **New Time Pattern** option.

When the new time pattern appears, change its name to **My Shift 1**. Next, click on the drop-down button next to the Time Pattern Type section to show the four options: Capacity, Efficiency, Arrival, and Other. The only two valid options for FactoryTalk Scheduler are Capacity and Efficiency, and we'll select the **Capacity** option. Now we need to select the Default Value Type. Clicking on the down arrow shows the four valid options: Numeric, State, Time Pattern, and <None>. In this case, we could select the Numeric option, followed by a 0 or 1 entry for the Default Value. However, for our example, we'll select the **State** option. (We'll talk later about the Time Pattern option, and the <None> option is not a valid FactoryTalk Scheduler application.)

In a new application, there may not be any predefined states. Open the States dialog by clicking on the button to the right of the down arrow for the Default Value field. Rightclick on the Capacity entry and select the **New** menu option. For our example, give it the name **My On Shift**. Since on-shift means that the resource will be available, you need to enter a 1 in the Value field. Next, click on the button to the right of the Fill Color field and select your favorite color. Your resulting creation should resemble the screen shown below. Accept these values by clicking **OK**. FACTORYTALK SCHEDULER USER'S GUIDE

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States		د د
State		
States:		
🐴 Arrival		Value:
茟 Capacity		1
💿 Available		
💷 My On Shift		Fill Color:
💷 Off Shift		
- 💷 On Shift		Line Color:
- 💷 Pool 3		
- 💷 Pool 4		Hatch:
Pool 5		<none></none>
🛄 💷 Unavailable		
A- Efficiency	-	
C	к	Cancel Help

We'll leave the Default Value as the Unavailable state. Next click on the button to the right of the Duration field to open the Time Pattern Duration dialog. Select the **Custom** option for the Duration Type and change the duration time to be **8 hours**, as shown below.

Time Pattern Duration		
Duration Type	ΠΚ	
C 1 <u>D</u> ay		
C 1 <u>W</u> eek	<u>C</u> ancel	
• <u>C</u> ustom		
	<u>H</u> elp	
<u>S</u> tart date:		
Sun, Jan 1,1995 💌		

At this point, we have defined a time pattern for a resource, which is unavailable for entire eight hours. Now we go to the Time Span section and double-click anywhere in the grid section to open the Time Span dialog. Select **State** for the Value Type field. Now select your new state, **My On Shift**, for the value field and change the start time to **0** and the end time to **8 hours**, as shown below.

Time Span		×
Value <u>Type:</u>		
Value:		-1
I My On Shirt		
Start: hr min 0 + 0 +		
End: hr min 8 1 0 1		
<u>0</u> K	<u>C</u> ancel	<u>H</u> elp

Time Patterns х <u>File Edit View</u> Time Patterns: Time Pattern Type Time Spans: 🔽 Lock Times 🔥 My Patterns Value Start Ŧ End 에 My Shift 1 My On Shift Default Value Type: 0:00 8:00 成 BizBikes 5 • State - 📌 2 By 5 Machine Default Value - 付 2 By 5 Pool 3 • Unavailable , 🖓 2 By 5 Pool 4 Duration: 🔥 2 By 5 Pool 5 8h 👌 Shift 1 👌 Shift 2 Scale Factor: 成 Sample Time Patterns l1 🐠 Sample Labor Work Weel 📣 Sample Preventive Mainte ۲ - 🖑 Sample Shift 1 📣 Sample Shift 2 • 2.00 ۲ -刑 Sample Shift 3 1.50 🔥 Sample Shift 4 ÷ 付 Sample Shift 5 H 1.00 👌 Sample Week 5 Days 🖑 Sample Week 7 Days 0.50 0.00 Þ 1/1/1995 8:00 1/1/1995 4:00 <u>0</u>K Cancel <u>H</u>elp

Accepting this dialog will populate the first row of the grid with your values. Note that the graph has now changed to show a capacity of 1 for the entire 8 hours.

Comparing this newly created time pattern to our first time pattern, Shift 1, shows that they are the equivalent, except for our new names. If you examine the Shift 2 time pattern, you should notice that except for the name, it is identical to the Shift 1 time pattern.

Now let's create the time pattern that we will attach to our singular resources. Create a new time pattern called **My 2 By 5 Machine**. Select the Default Value Type as **State** and the Default Value as **Unavailable**. Change the Duration to **1 week**. Now double-click in

Time Span		×
Value <u>T</u> ype: Time Pattern ▼		
Value: My Shift 1	•	
Start: day hr Mon ∓ 7 ∓	min 0 🔹	
End: day hr Mon + 15 +	min 0 ÷	
<u>0</u> K	<u>C</u> ancel	<u>H</u> elp

the time span grid and assign the new My Shift 1 time pattern to the hours from 7 to 15 for **Monday**, as shown below.

Accept this dialog and enter a new time span that assigns time pattern **Shift 2** on **Monday** from **15** to **23**. Continue repeating these entries for Tuesday through Friday. The resulting Time Pattern is shown next.

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The only difference between this new time pattern and the 2 By 5 Machine time pattern is that we did not define the off-shift times. We simply allowed those times to be assigned the default state **Unavailable**; the results are the same. The only reason the off-shift state was used in the original time pattern was to allow us to assign a color that would be displayed whenever we viewed the time patterns in FactoryTalk Scheduler.

Now let's take a look at the **2 By 5 Pool 3** time pattern that is assigned to our Labor resource. It has a Default Value of state **Unavailable** (0 capacity) with the same time entries in the Time Span section as the 2 by 5 Machine time pattern. Pool 3 state was assigned a value of 3 when it was created, as shown next.



The resulting 2 By 5 Pool 3 time pattern looks very similar to the 2 By 5 Machine time pattern, except for the capacity of 3 during the on-shift times.



Now let's assume that one of your resources performs at a 90% level. Let's develop a new efficiency time pattern named **Machine At 90**. Select the Time Pattern Type as **Efficiency**, the Default Value Type as **Numeric**, and the Default Value as **0.90**, as shown below.

Time Patterns				×
<u>F</u> ile <u>E</u> dit <u>V</u> iew				
Time Patterns:	Time Pattern Type:	Time <u>S</u> pans:		🔽 Lock Times
My Patterns	Efficiency 🗾	Value	Start	End
Mu 2 Bu 5 Machine	Default Value Type:			
My 2 by 3 Machine	Numeric 🗾			
📆 BizBikes 5	Default Value:			
2 By 5 Machine	Ju. 30000			
2 By 5 Pool 3	1 Day			
2 By 5 Pool 4	Scale Factor			
Shift 1	1			
Shift 2				
🔞 Sample Time Patterns		•		•
Sample Labor Work W				
Sample Shift 1	1.80			
Sample Shift 2	1.35			
🚽 🤯 Sample Shift 3 📃	0.90-			
Sample Shift 4	0.45-			H
Sample Week 5 Daus				
	8/11/2002 0:00	8/11/2002	12:00	8/12/2002 0:00
				1
		<u></u>	K <u>D</u> ancel	Help

Note that there are no entries in the Time Span section. We simply allow the efficiency to be at value 0.9 for the entire time period, as the capacity time pattern will be overlaid.

The time patterns we developed describe a standard work week that our manufacturing system will follow. We now need to consider exceptions to these repeating patterns.

Developing exceptions

There are two basic types of exceptions that need to be included in our shop schedule: global and resource specific. Global exceptions generally apply to the entire manufacturing system. Examples would be a company-wide shut down or holidays. To illustrate how to use the Exceptions Editor, we'll add the Fourth of July as a holiday.

Select the **Database > Time Pattern > Exceptions Editor** menu option to open the Exceptions Editor. Double-click in the grid area to open the Exception window. We'll set the Exception type to **Capacity** and name our exception **July 4**. Select the Value type to

be **State** and the Value to be the state **Unavailable**. Now use the drop-down arrows to open the calendar and set the Start Date to **July 4** and the End Date to **July 5**. Next, highlight the Resources entry in the Elements section and press the double arrow symbol (>>). This will cause all the resource names to appear in the Application section. In effect, we have requested that this exception be applied to our entire system. Expanding the Resource entry would allow you to apply the exception to individual resources. Your resulting exception should look as follows.



By accepting this dialog, you will return to the Exceptions window that will now contain the new schedule exception.

Attaching a time pattern

Having created time patterns that define the capacity and availability of resources, you must now associate or attach them to the resources that will use them. We do this using the **Database > Time Pattern > Composite Editor** menu option, which will open the Composite Time Patterns Editor window. For a FactoryTalk Scheduler application, you will need to attach or associate a time pattern directly to a resource. To do this, expand the Resources tree until each resource in your application is visible. Then select a resource by clicking on the Capacity or Efficiency directly under the resource. You then select the Value Type, Time Pattern, and the Value from the drop-down lists. In our tutorial, you

would want to attach the 2 By 5 Pool 3 time pattern to the Capacity selection of the Labor resource and the 2 By 5 Machine time pattern to the Capacity selection of the remaining resources. The Capacity selection for the Bender resource is shown below. You should also note that the July 4 exception we created in the previous section is listed in the Exceptions section of the Composite Editor window.



You can also enter exceptions in this editor by double-clicking in the grid section to open the Exceptions window.

For our tutorial system, we defaulted on the Efficiency time patterns. If you wanted to reduce one of your resources to an efficiency of 90%, you would simply attach the Machine At 90 time pattern that we just created.

Summary

We have provided you with a brief overview on how to use the time pattern editors, which should allow you to develop most of your application's time patterns. There are other features available that have not been covered here. If your schedule has special requirements, we recommend that you take advantage of the online help files.

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