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IMPROVING ORDER FULFILLMENT PREDICTABILITY PERFORMANCE

by
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Submitted to the Departments of Electrical Engineering and Computer Science
and to the Sloan School of Management in Partial Fulfillment of the
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and
MASTER OF SCIENCE IN MANAGEMENT
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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ABSTRACT

This thesis is based on an LFM Internship at Digital Equipment Corporation's (DEC) Salem, NH facility. This factory is DEC's largest workstation manufacturing plant. The internship involved developing a process flow map of the order fulfillment process and business practices. A simulation model was then built based on this process flow using Witness™ software. Ideas for improving the predictability and cycle time of order fulfillment were experimented with using this model.

It was determined that the area of greatest possible improvement was the scheduling for delivery of a customer order. By using material availability information in this activity, modeled order fulfillment predictability was improved significantly. A software tool is outlined and proposed for the implementation of this type of scheduling procedure. This tool is being implemented by Digital.

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Digital Equipment Corporation supported the work wholeheartedly from beginning to end. Their support of LFM in general and of me in particular is greatly appreciated. Dave Mentzer, the Technology Manager at the site where the work was conducted gave the proper level of direction and allowed a level of autonomy appropriate to the author's abilities. This was much appreciated.

Professor Chrysanthos Dellarocas at Sloan School of Management provided direction and encouragement with what seemed to be perfect timing. When I was confounded with some aspect of the research, he would often provide a steering in the appropriate direction. Professor Steve Leeb was also very helpful, particularly in terms of the content of the final document. Both of these advisor relationships are greatly appreciated.

Finally, I acknowledge the patience and help of my wife. Allison was patient in waiting for my schooling to be completed and excited for my personal accomplishment. She was also quite helpful along the way with proofreading and more importantly constant encouragement. Her presence in my life is a great gift and I am thankful for her.

Chapter One: Intent and Overview

1.1 Problem Definition and Intent

The intent of this effort was to find ways to improve order fulfillment predictability in the Digital Equipment Corporation's(DEC) workstation manufacturing operations in Salem, NH. At Digital, "order fulfillment predictability" is defined as the percentage of the time that orders are delivered to the customer on time. This project was initiated by the Technology Manager for the Salem facility (also called NIO internally).

Predictability was in the range of 50 to 65% at the initiation of this project. The corporate goal was 95%. The industry average for predictability is 80 to 85%.¹ Field personnel report that customers see low predictability as a major reason not to buy from DEC. Customer focus groups have also revealed low predictability as a major impediment to sales. For these reasons, the company feels that it needs to be more competitive in this area. The goal of this thesis is to provide an unbiased look at the Salem facility and its business procedures and suggest concrete ideas for improvement.

1.2 Overview of Method

The plant Technology Manager had a fairly good idea of how the analysis of the organization should be done. The first step was process mapping. This was to involve interviewing people within the organization at all levels in order to identify what the actual business practices are. These practices were then to be documented using activity based flowcharts. The second step was modeling. This would involve building a simulation model of the order fulfillment process. This model would be built based on the information collected in the first step. A

¹ Anne DiCenso, Research conducted for thesis for LFM Program, 1997.

final step was to make suggestions for improvement based on observations made of the model. This plan of action matured into a six step process upon which the research was based.

1. Construct basic flow for the Desktop portion of operation.
2. Collect data to characterize the flow of product through the facility.
3. Build a simulation model of the manufacturing process.
4. Identify possibilities for improving business practices.
5. Test proposed improvements on a simulation model.
6. Recommend best improvements and submit formal proposal.

This six step plan is similar to the original plan, with the addition of a data collection step. Data collection was seen as critical for two reasons. First, it would put the author in closer contact with the real business activity in the plant. This would provide a more complete understanding of the process. Second, it would provide real necessary for the modeling process.

1.3 Focus of Research

There are three families of products produced at Salem: Desktop, Deskside and Data Center. Each of these families will be described in greater detail in Chapter Two. All of the research activities in this six step process were conducted in the Desktop portion of the business. This family of products comprises roughly two thirds of the order fulfillment activity. The other one third of the orders are in the Deskside and Data Center portions of the business.

The scope of the research was limited to the Desktop family due to time and resource limitations. Given that there was substantial up front work necessary in the form of process mapping and simulation model building, we did not think it possible for the author to fully implement any solution. For this reason, step six

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requires a detailed proposal of some system, tool or business practice change. This allows for the work to be implemented after the short six month internship. This implementation would be done by Digital employees who will be in a better position to oversee the process.

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Chapter Two: Product and Facility Description

2.1 Product Description²

DEC uses the Alpha³ processor technology in three product families which are manufactured at the Salem facility. The product families are Desktop, Deskside and Data Center. Within each family, both workstation and server types of machines are produced, with the exception of the Data Center line where no workstation units are produced. This information is summarized in Table 2.1-1.

	Desktop	Deskside	Data Center
Workstation	yes	yes	no
Server	yes	yes	yes

Table 2.1-1: Product Type Within Family

Desktop products are the lowest priced and sized of the three. They easily fit on a desk. Deskside products are higher priced and somewhat larger. They are designed to sit upright next to a desk. Data Center products are the highest priced. They are large cabinet units typically configured with modules containing disk drives, memory and a CPU module.

A typical application for a Desktop unit would be a 2D or 3D CAD (computer aided design) station. Typical applications for Deskside units range from an individual 3D CAD station to a multi-application server for a small department within a larger business. Data Center products are used for large business server applications and more specifically for applications requiring strong data input and output (data I/O) capabilities.

² All product information compiled from DEC product catalogues.

³ Alpha is a trademark of Digital Equipment Corporation.

2.1.1 Product Design and Performance

Computing power and product design vary widely within the three product families. In general, the Desktop products are less flexible in terms of CPU configuration. Memory availability is flexible, but the processor within a product designation is fixed. The higher end Data Center products allow the customer to vary the number of processors used as well as the amount of memory available. This is discussed in more detail below.

2.1.1.1 Product Design and Manufacturing Methods⁴

The product design and configuration lends itself to the method of manufacturing used for each family.

Desktop Product Design and Manufacturing Method

The Desktop products are built on a semi-automated (automated part kit delivery only) assembly line where kitted parts are shuttled to the assembly worker via a computer-controlled roller track. This is reasonable given the single motherboard (within family) with multiple expansion slot configuration. Each product line has a similar chassis with built-in expansion slots. The overall chassis size is about 4" tall by 17" wide by 16" deep. Extra hard drives, communication cards, memory or other options are plugged into an available slot in the chassis. Problems can occur if the unit is ordered with more options than slots.

Deskside Product Design and Manufacturing Method

⁴ Manufacturing method information based on research conducted by the author.

The Deskside products are built by one individual in a similar, but less automated fashion. Each family of products has a common chassis with multiple expansion slots for hard drives, communication cards, memory or other options. The overall chassis size is about 20" tall by 10" wide by 26" deep. The board-level architecture differs from the Desktop family. A single motherboard is used, with multiple (up to two) CPUs available on a single motherboard. Daughter cards plug into the motherboard for further expansion. This increases the speed with which the internal data transmission can occur and also increases the I/O capability.

Data Center Product Design and Manufacturing Method

Data Center products are built by a team of people who bring pre-constructed modules to the chassis and fit them onto the machine. The design philosophy used on these units is a departure from the Desktop and Deskside units. The chassis is a large cabinet (the size of a small refrigerator) designed to hold the modules. The modules are built in surrounding areas and brought to the chassis and mounted and wired in. This type of assembly is necessitated by the physical size of the components required to deliver this level of performance.

2.1.1.2 Product Performance

Digital has matched the performance of each family of products to meet the intended application. Table 2.1.1.2-1 lists the intended application for each family and corresponding system requirements.

The processing capabilities of each family are shown in Figure 2.1.1.2-2. Processing capability is shown in terms of millions of instructions per second (MIPs). The processing capability is accomplished by different means in each product family. The Desktop family uses a single Alpha processor running at a clock speed of 100 to 400 MHz. The Deskside family can be configured with

either one or two Alpha processors. These Alpha processors have clock speeds from 233 to 400 MHz. The Data Center products can be configured with anywhere from six to 12 Alpha processors running in a parallel manner. This allows the same processor chip technology to be leveraged over three different families, correlating to a 50-to-1 difference in computing capability from the lowest to highest powered Digital product.

Family	Typical Applications	System Needs
Desktop	2D, 3D CAD Other Computationally demanding applications	Low-to-Medium processor speeds Medium amounts of RAM Minimal I/O capability
Deskside	Small Server Applications 3D CAD Highly Computationally demanding applications	Medium Processor speeds Large amounts of RAM Medium I/O Capabilities
Data Center	Large and Very Large Server Applications	Very High speed processing capability Very large amounts of RAM Very high I/O capability

Table 2.1.1.2-1: System Requirements for Families of Products

Figure 2.1.1.2-3 illustrates the RAM (Random Access Memory) available within each product family. Once again, the difference from the top to the bottom of the product offering is tremendous (8 to 14000 Mbytes). All units use SIMM (Single In-line Memory Module) type memory.

The data input and output (I/O) capabilities vary widely among families. This is shown in Figure 2.1.1.2-4. All Desktop products come equipped with 132

Mbyte/sec I/O capability. Deskside units come with either 132 or 264 Mbyte/sec I/O capability. Data Center products have a much higher I/O capability and a

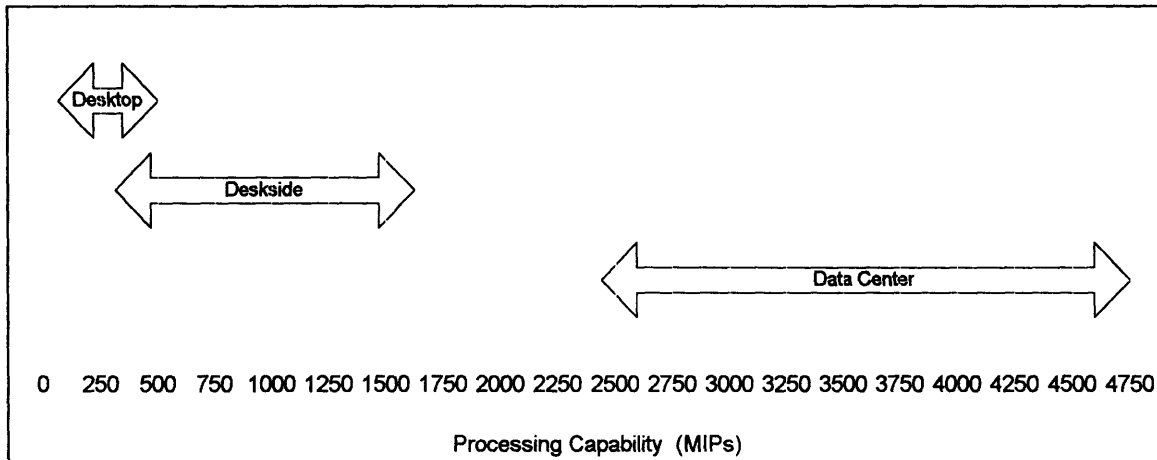


Figure 2.1.1.2-2: Processing Capability for Digital Products by Family

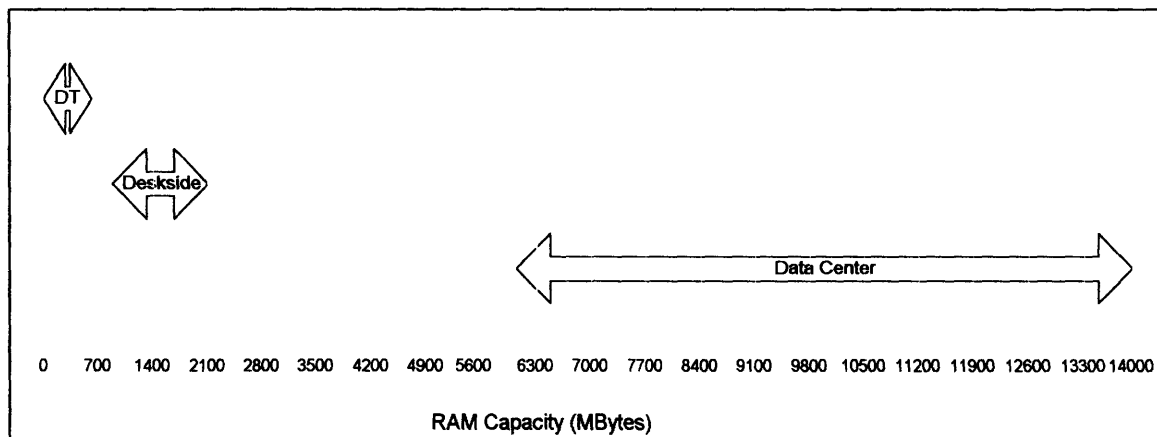


Figure 2.1.1.2-3: RAM Available for Digital Products by Family

much wider range of offerings. This matches the need of an enterprise server: extremely high I/O capabilities.

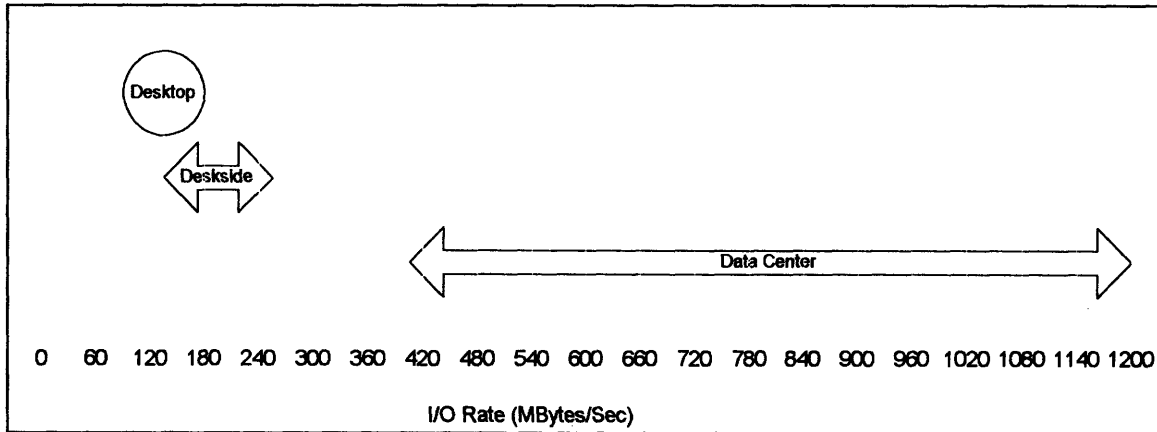


Figure 2.1.1.2-3: I/O Capabilities for Digital Products by Family

2.2 Evaluation of Product Design Strategy

Digital offers a very wide range of products based on its Alpha processor. It is clear that the center of their product design strategy is the leveraging of this common processor technology across three families of product. The use of a single processor across all families of product causes the volume of Alpha processors used to be higher than if a unique chip were used in each product family. This strategy has some distinct business advantages.

First, it provides an opportunity for DEC to gain economies of scale in equipment. All levels of equipment used to manufacture the Alpha processor and assemble it onto motherboards within all three product families will be similar. This allows savings on the cost of this equipment that would not be possible if a different processor were used in each family.

Second, economies of scale are gained in process knowledge. For each process involved in manufacturing or assembling Alpha processors to motherboards, the greater volumes allow quicker learning. This enables DEC to improve these processes in a shorter timeframe than if they had different processors for each family.

Finally, economies of scale develop in the area of product design. DEC's product designers can focus on the application of a single processor technology.

This could allow for shorter design cycles as knowledge about the application of the processor increases. If several processors were used, the design engineers would have to manage multiple knowledge bases, rather than focusing on the Alpha processor.

The major disadvantage of centering product design on a single processor technology is that the risk of failure is not distributed. If a multi-technology approach were taken, the failure of one of those technologies would have only a partial impact on the business. The other technologies would provide continuing business. With a single technology approach, a failure of that technology has a much greater impact.

2.3 Physical Plant Description⁵

The Digital Salem facility is comprised of two buildings: a warehouse and a factory connected via a traffic conduit. The factory is 539,300 square feet in size and the warehouse is 138,800 square feet. A simple diagram of the facility is shown in Figure 2.3-1. The System Business Unit (SBU) manufacturing is located in "Core D". This area houses the manufacturing operations for all three families of product studied. The Computer Systems Solutions (CSS) manufacturing is located in "Core C". More complex and unique products are built in this area. This area was not studied. All order processing, materials acquisition, planning and other support activities are conducted in "Core A".

⁵ Information taken from plant documentation and observation of author.

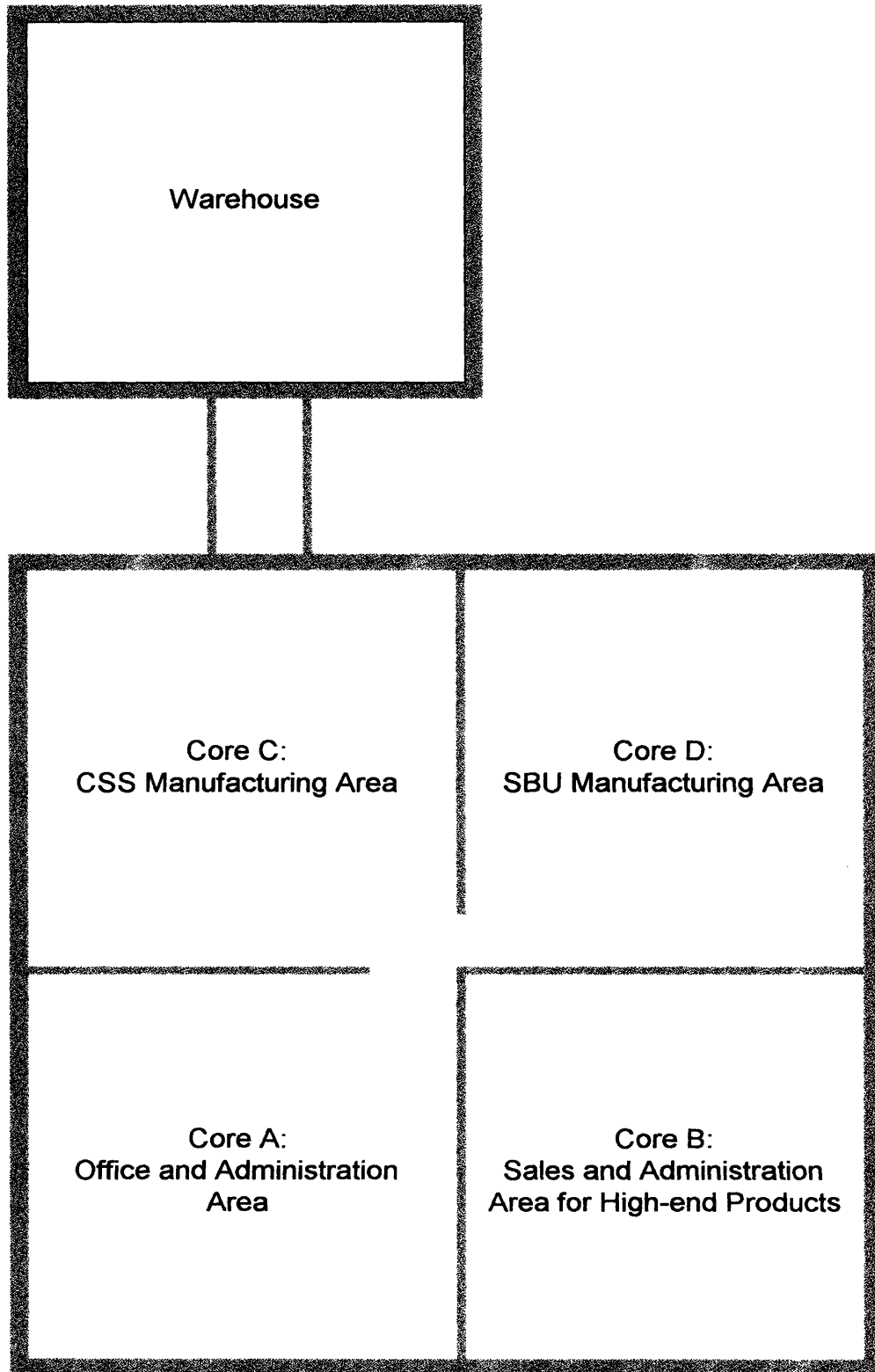


Figure 2.3-1: Salem Facility Lay-out

A more detailed lay-out of Core D is shown in Figure 2.3-2. Roughly even floorspace is given to each family of products. The shipping area serves all three families. It has about 2000 square feet of holding area from which units are then moved onto trucks via three full size bays.

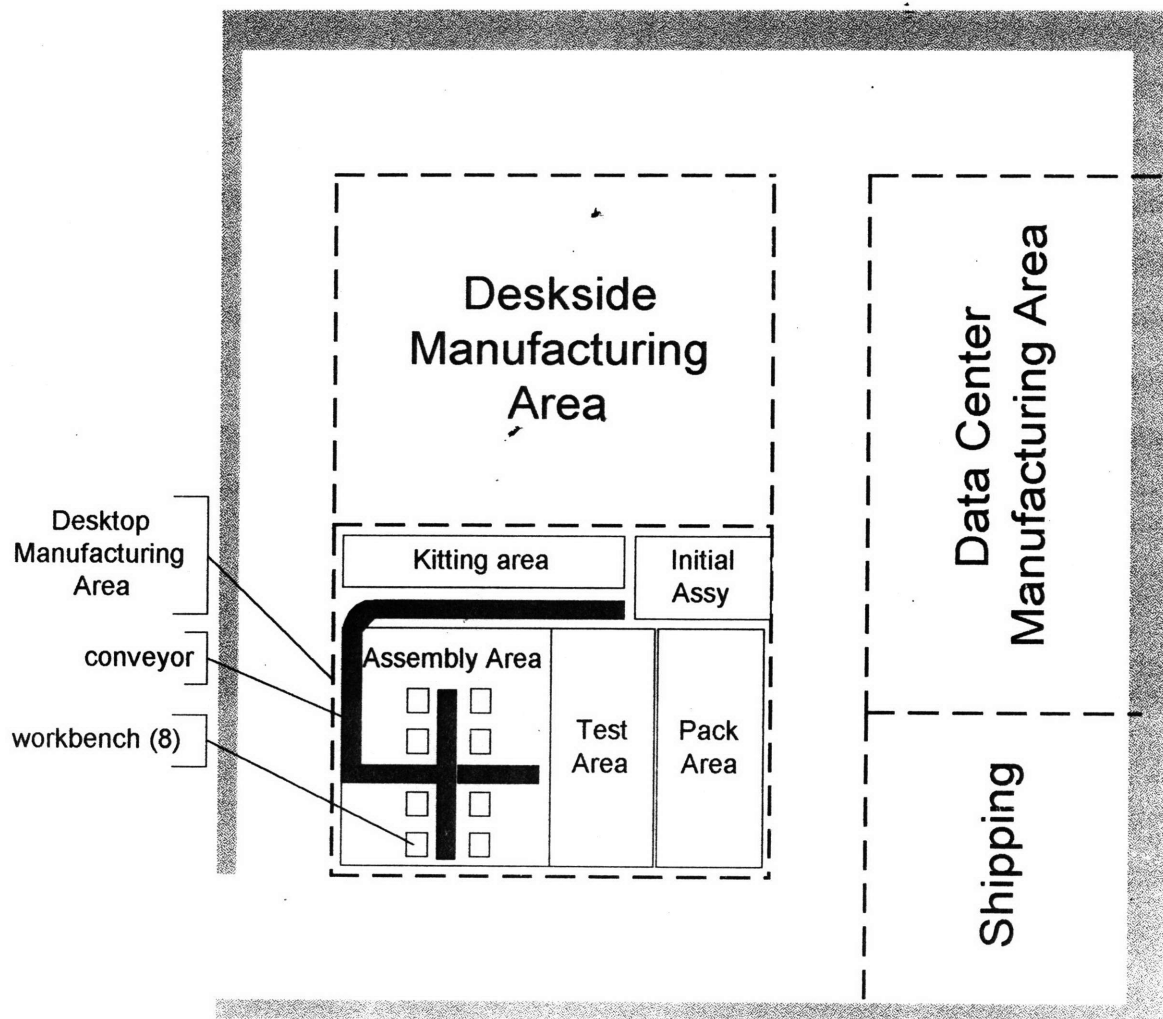


Figure 2.3-2: Detailed View of Core D

More detail is shown on the Desktop manufacturing area, since this is the area which will be studied in depth. There are five major operations within the

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Desktop area: initial assembly, kitting, assembly, test and packaging. The first three are connected via a 3' wide rolling conveyor. The initial assembly area is comprised of two work areas in which the chassis and power supply sub-assemblies are assembled and pre-tested. A "pick-to-light" type line is used to build assembly kits for each order. The "pick-to-light" line consist of a row of bins containing parts. Each bin has light emitting diode (LED) below it. When an order comes to the assembly area, its bill of materials is read into the controlling computer system, lighting up the appropriate bins. A technician then pulls the appropriate materials from the lit bins only and places them into a tote. This tote and chassis are sent via the conveyor to one of eight assembly technicians. After assembly is complete, the product is hand carried to the test area where it is placed in one of 240 test slots and tested. After test, it is carried to the pack area where it is packaged for shipment.

Chapter Three: Order Fulfillment Process Documentation

3.1 Process Documentation Method⁶

As stated in Chapter One, the first step of the internship process was to map out the flow of information, materials and orders through the facility. The steps involved in this activity are:

1. Record all possible sources of input to activity.
2. Capture the actual activities being performed.
3. Capture time required to perform these activities.
4. Record all possible types of output for activity.
5. Record decision logic to determine output routing.
6. Define organizational boundaries.

Two different techniques for activity mapping were considered for this effort. The first was an existing technique used by DEC. An example of this technique for the order release process is shown in Figure 2.3.1-1. The organizational boundaries are represented by the five vertical bars. Various figures represent activity start, stop, inputs, parallel paths and interactions between parties. When more detail is needed than can be shown on a single sheet, a numerical reference is made to another sheet. The strengths of this method are that it illustrates organizational boundaries well, it shows a large portion of the decision path on one page, and it documents information paths well. The major weakness is that there is very little activity-level detail documented for each

⁶ All process information documented in this chapter is based on research conducted by the author.

activity. Also, so much information is given on one page, it was difficult at times to understand the overall picture.

The second method considered, and used for this work, was the activity-based method shown in Figure 3.1-2. This method is based on one outlined by Malone et al.⁷ This is the process documentation for the building procedure on the Desktop line. Organizational boundaries are not defined using this method. Each box, including the large one which is around all of the smaller boxes on the page designate an activity taking place. Arrows indicate inputs or outputs from this activity. Heavy lines indicate material flow into or out of activity. Lighter lines indicate information flow into or out of activity. The major advantage of this method is that it gives the user a choice in the level of detail

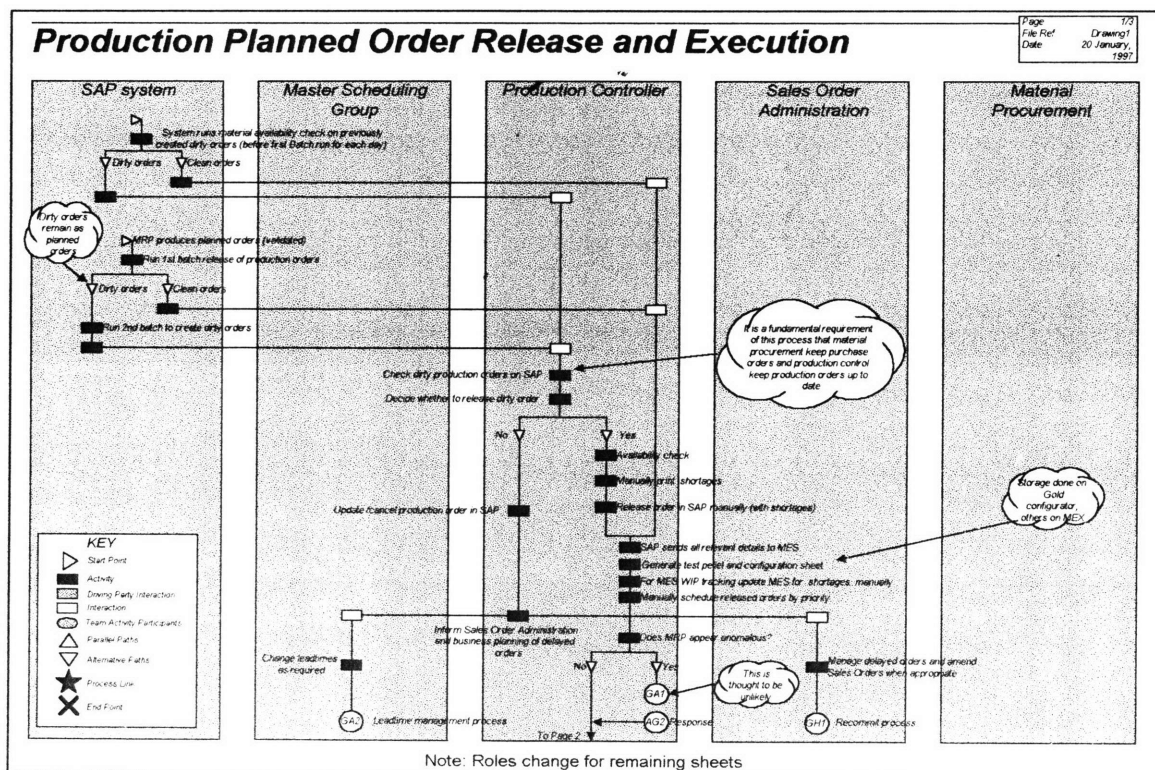


Figure 3.1-1: Example of Existing DEC Method of Process Documentation⁸

⁷ Thomas W. Malone et al. Tools for inventing organizations: Toward a handbook of organizational processes. Sloan School WP# 3562-93. (Cambridge, MA: MIT Sloan School of Management, 1993).

⁸ Internal DEC process documentation, used with permission.

used. The user can easily go up one level of detail to a top level view of the entire order fulfillment process as shown in Figure 3.1-2. The number 21 with a circle around it is a reference to the next level up.

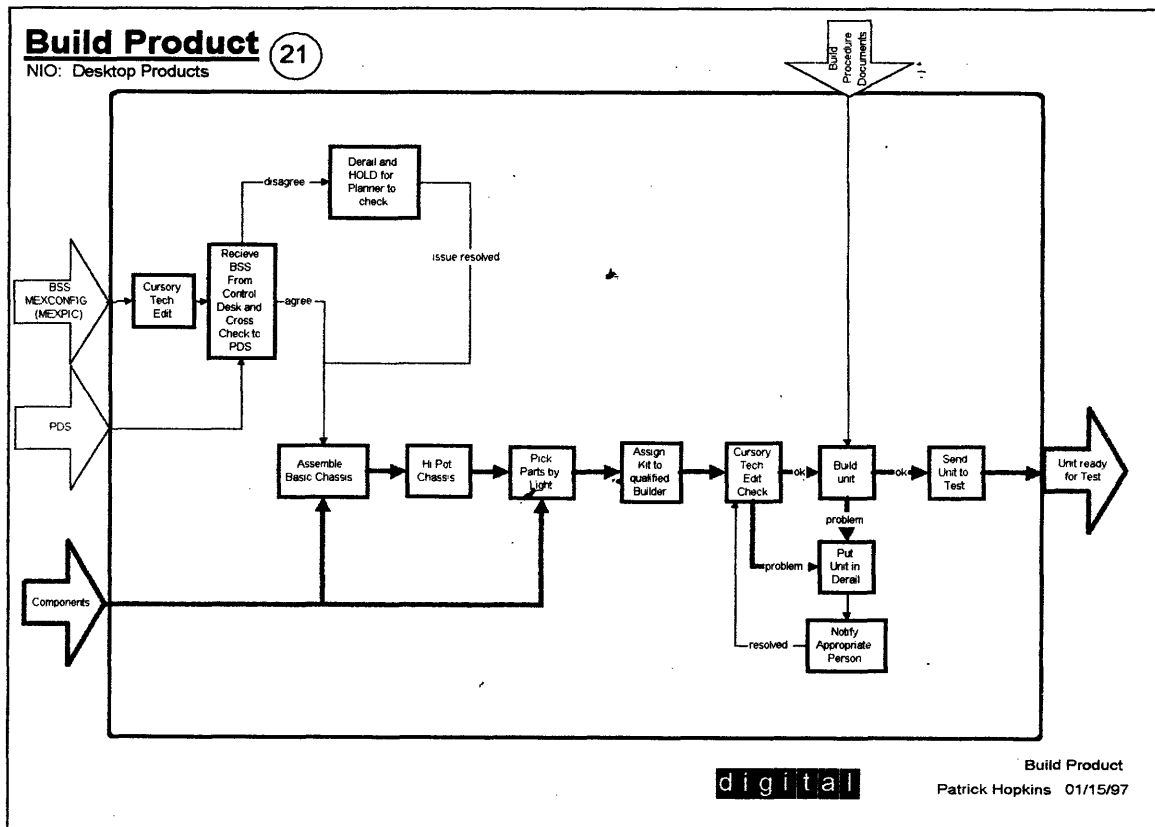


Figure 3.1-2: Example of Activity Based Process Documentation

The circled 21 can also be located on the top level process map in Figure 3.1-3. This level of detail is useful for orienting or re-orienting oneself to the overall process. Looking in greater detail within each activity box is then simpler and more understandable.

Another advantage is that inputs and outputs are more easily documented and much more visible than with the other method. The major disadvantage of this method is that organizational boundaries are almost invisible. At the top level, the activity boxes are color-coded by organization, but no further

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documentation is shown at any other level. Knowledge of organizational boundaries is important when changing the activities to improve performance. However, the focus of this study is the actual activities which comprise order fulfillment. Therefore, this tool was chosen due to its greater emphasis on activity documentation.

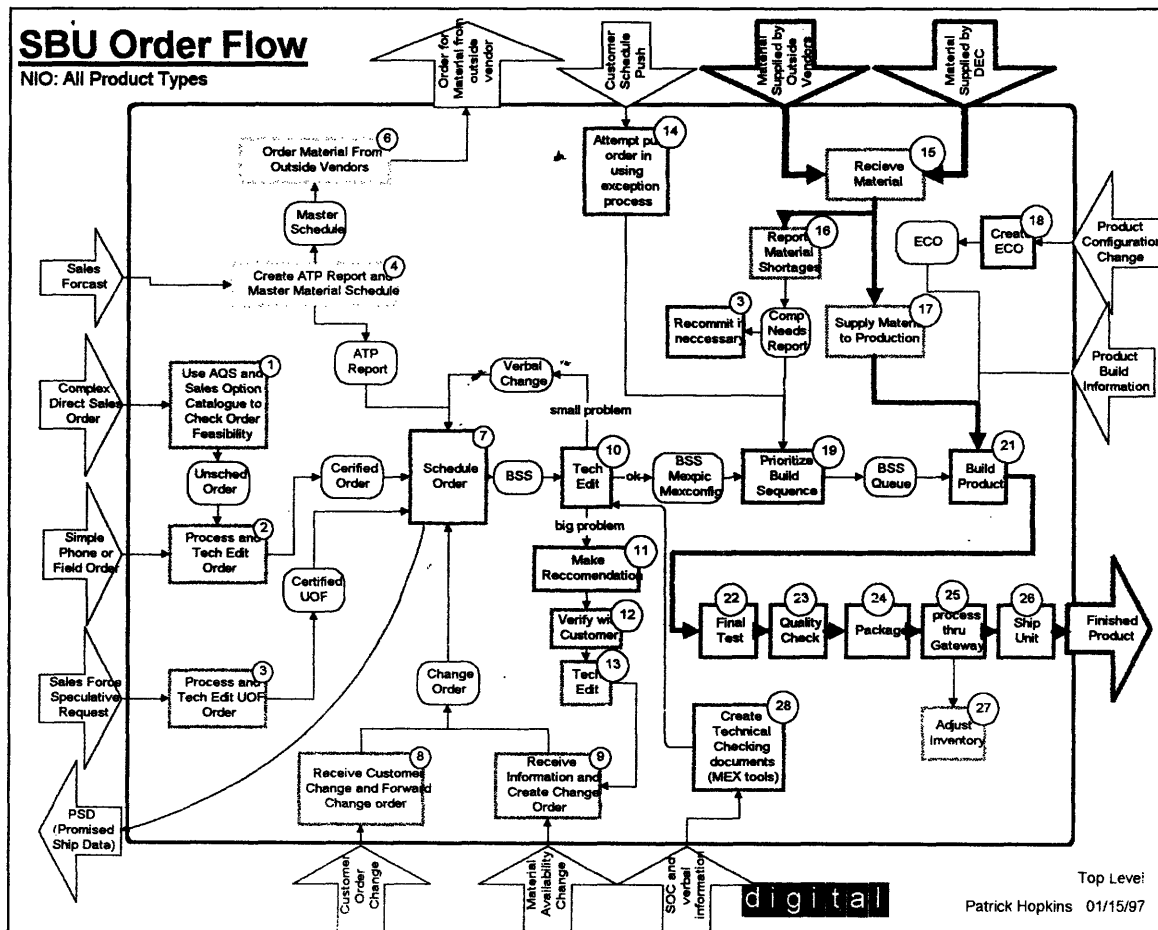


Figure 3.1-3: Top Level Process Documentation of Order Fulfillment Process

3.2 Documentation of Order Fulfillment Process

Once the documentation method was defined, the job of documenting each step of the order fulfillment process began. This corresponds to Step 1 as defined in Chapter One. To get a rough overview, most department managers

were interviewed. Then each step in that overview was expanded using interviews with the people who actually performed the tasks. The overview was adjusted during these downstream interviews in areas where more information, or more up to date information became available. For each step in the process, a mean cycle time was determined by the employee. A worst case time was also determined and in most cases, a log-normal distribution was a good approximation to the actual cycle times.

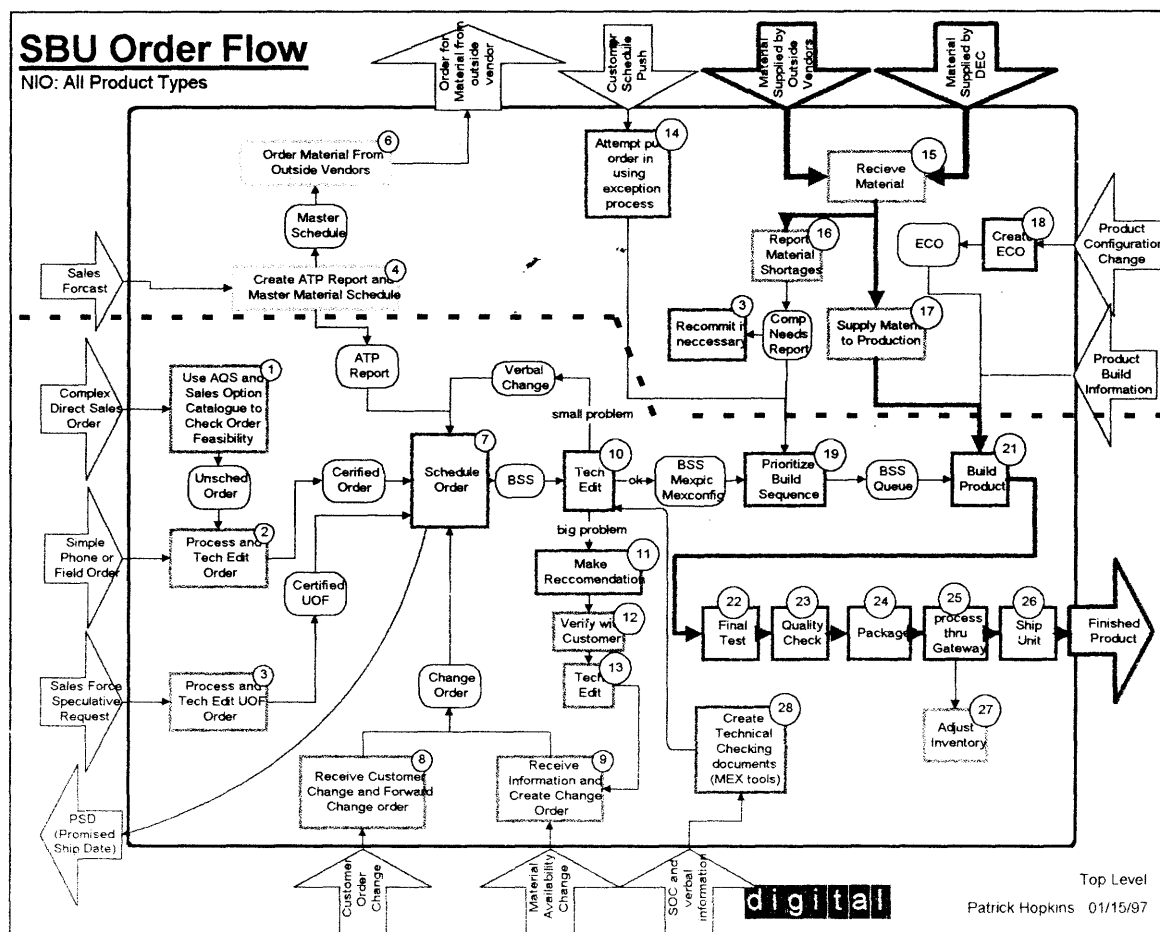


Figure 3.2-1: Top Level Process Documentation of Order Fulfillment Process

The top level process map for the Desktop business is shown in Figure 3.2-1. The remaining maps, one level of detail down from this one are in Appendix Two and will be referred to in this section.

This top level map represents the process as a whole. There are two types of activities occurring: those which occur in parallel with the order and those which occur sequentially with the order. Activities shown on the top level map which are above the dashed line are parallel activities. These activities occur independent from the order handling and are generally support activities. Those activities below the line are sequential activities. These are the activities that occur in a certain sequence for each order processed. The activities are listed in these groups in Table 3.2-1 and explained in detail in the remainder of this chapter.

Parallel Activities	Sequential Activities
Sales Forecasting	Order and Customer processing
Material Acquisition	Scheduling
Material Planning	Technical Editing (check)
Engineering Design Change Mgmt.	Prioritize for Production
	Assemble Product
	Test Product
	Quality Check
	Package Product
	Shipping

Table 3.2-1: Activity Breakdown by Type

Parallel Activities

The production process is forecast driven. The sales forecast for the present quarter is done five weeks earlier in the previous quarter. This activity is performed by a corporate forecasting group. Material acquisition is done using a fairly standard MRP (material resource planning) system, which is loaded with the forecast. More detail for material acquisition is shown in Figure 3.2-2.

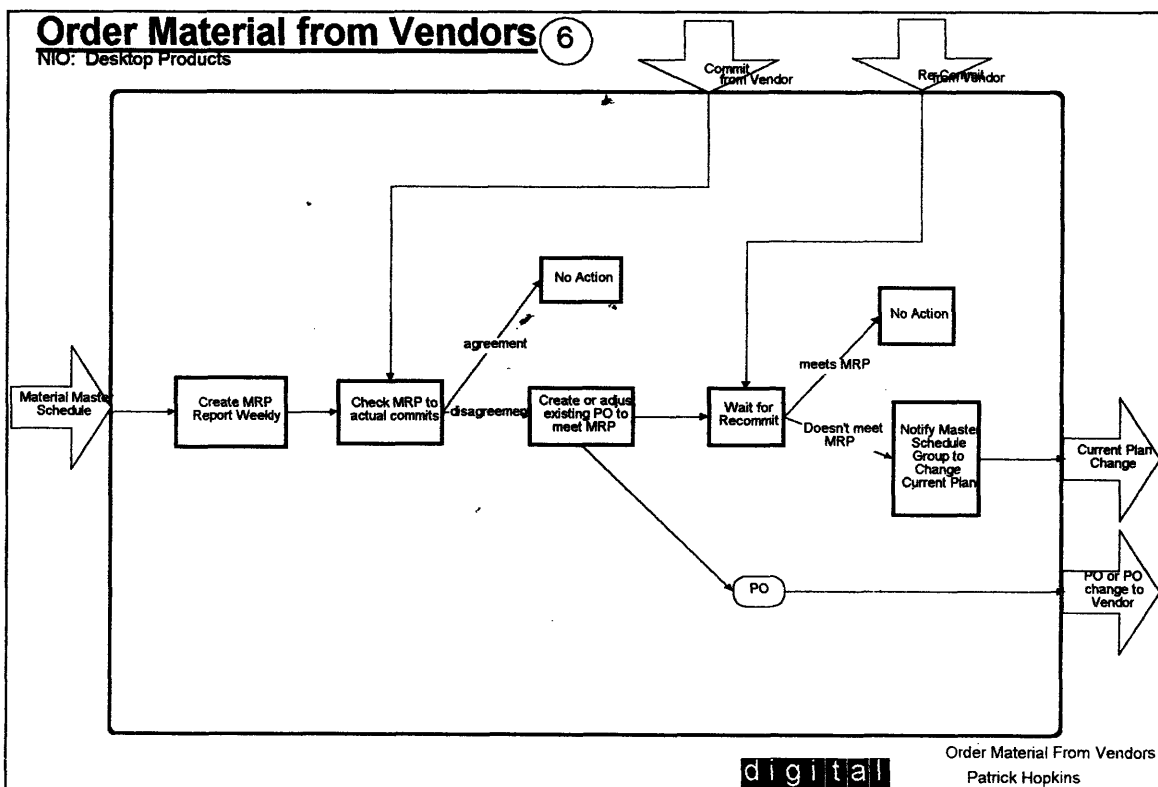


Figure 3.2-2: Material Acquisition Process

The material purchase orders (POs) are issued strictly according to the MRP system. As new products are introduced, their sales are similarly forecast and their bills of material are added to the MRP system.

Sequential Activities

As orders come in, the sequential activities begin. The first step is to process the order and customer. This activity is defined in Figure 3.2-3.

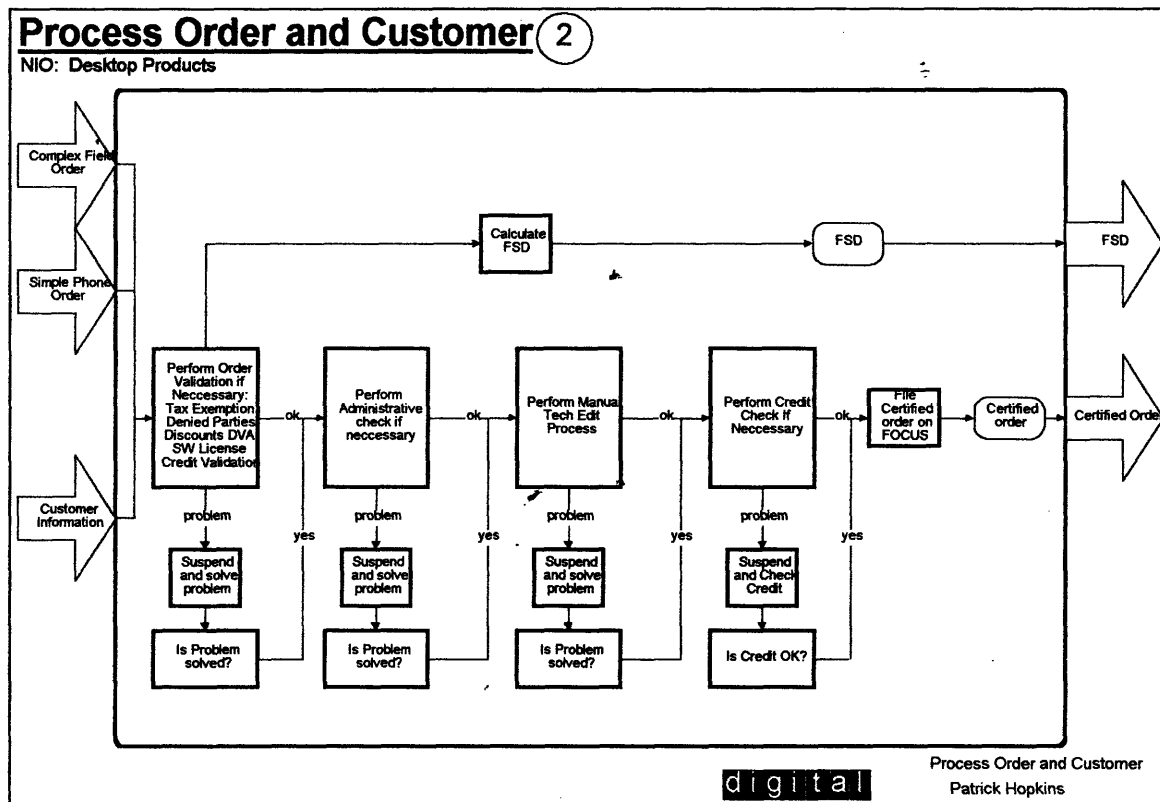


Figure 3.2-3: Order Processing

Orders are received in many different manners, but generally fall into two categories: complex field orders managed by salesmen and fairly simple phone orders taken directly from the customer over the phone. Both types of orders undergo the same process:

1. Order validation: check for tax exemptions, denied parties and discounts

2. Administrative check: determine if all required administrative information is present.
3. Technical edit: perform a cursory technical check of the order to make sure it is feasible.
4. Credit check: new customers only

These activities typically take one day, but often are held up for three or more days if a problem is found and needs correction.

The order is then scheduled. This operation is performed by order administration personnel. The process is outlined below in Figure 3.2-4.

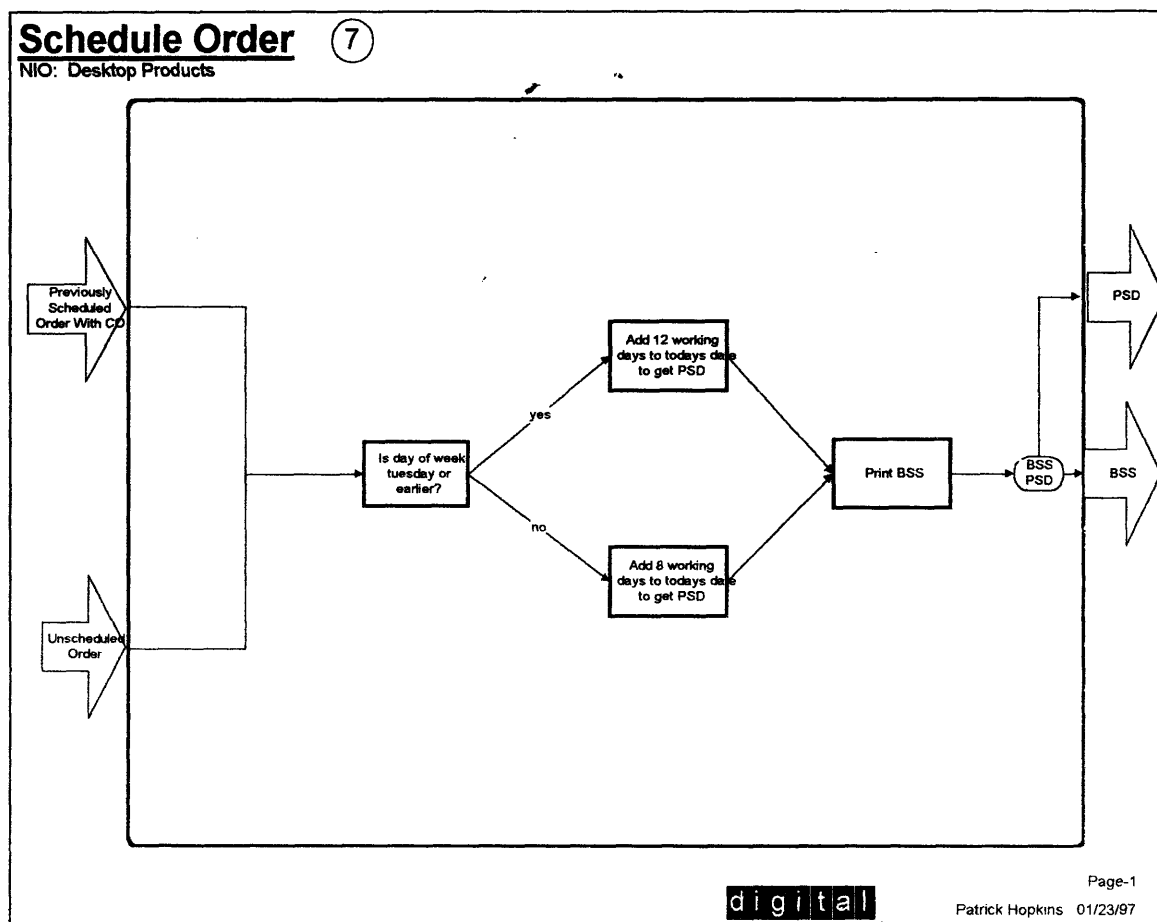


Figure 3.2-4: Scheduling Process

There are two types of inputs to the scheduling activity: unscheduled orders and previously scheduled orders with change orders (COs). Both are treated in the same way. The goal is to assign a promised ship date (PSD) to the order according to the procedure. The procedure is a modified leadtime scheduling technique where if it is Tuesday or earlier, 12 working days are added to the present day's date to find the PSD. If it is Wednesday or later, only eight working days are added. The PSD is fed back to the customer and the build ship sequence (BSS) paperwork is printed and passed on to the technical editor. The BSS is a printout of some customer information and a full description of the machine or machines to be built. It is important to note that material availability is not checked before a promised ship date is determined.

The order is then technically edited (tech edited). This activity is documented in Figure 3.2-5. The order is first sorted into one of three

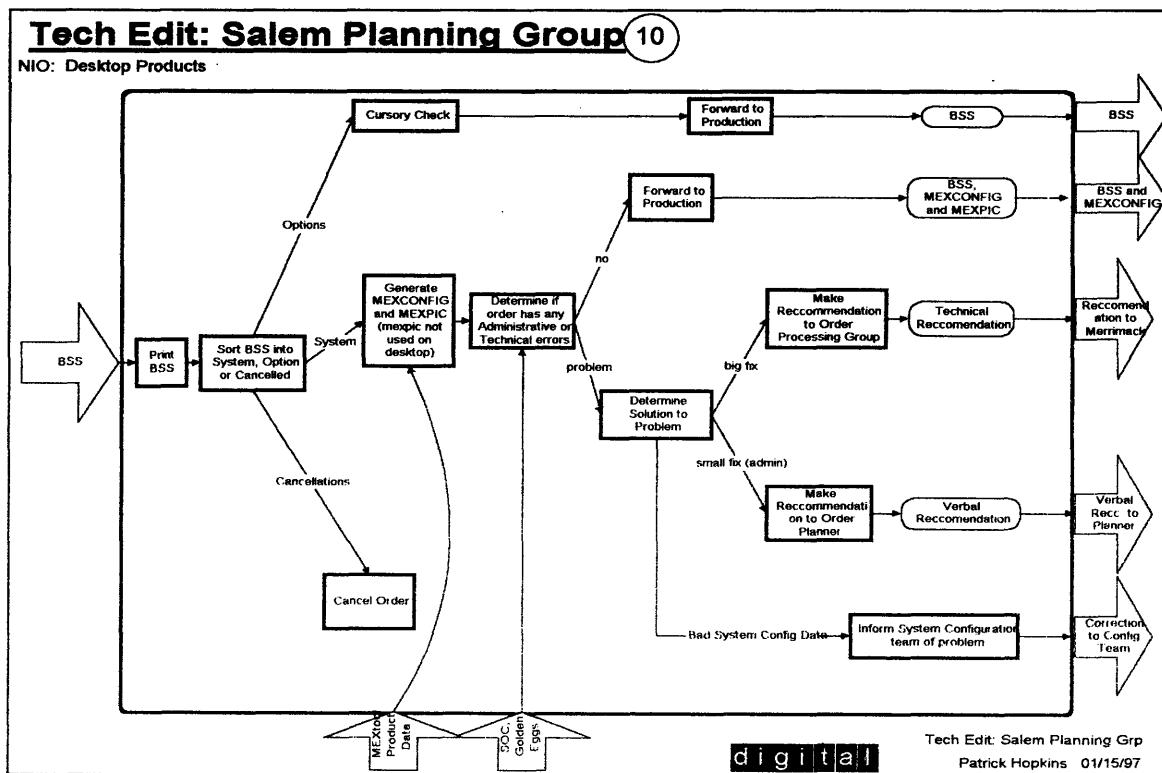


Figure 3.2-5: Technical Editing Process

categories: options, systems and cancellations. Options are system add-ons like memory, power cords or disk drives. System orders are the type that will be studied. For these orders, a technical documentation software tool is used. A configuration document is printed for all Desktop orders using this tool. This document transfers all available engineering documentation which applies to this order onto a set of sheets. The software finds any incompatibilities or configuration violations as specified by the engineering documentation. If there is a problem, it must usually be addressed with the customer. This requires the order to be returned back to the beginning of the process. This activity will produce a change order that will be attached to the order as it passes back through the process again. If there is a small administrative fix required with the order, this is often handled between the tech editor and the scheduler without the formality of a change order. After the order is determined to be technically viable it is passed on to production control to be built.

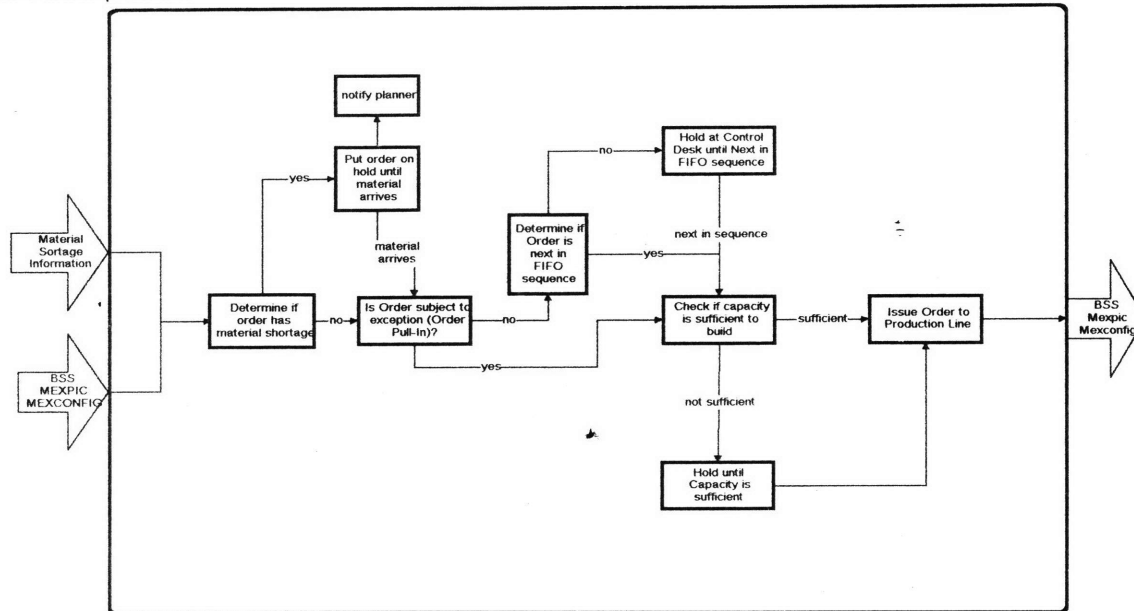
Figure 3.2-6 shows the process used by production control to determine when an order is issued to the production floor. Material availability is checked first. If material is available, then the orders are issued to the floor in FIFO (first in first out) order according to PSD. The exception to this rule is if the order is being expedited or pulled-in according to a corporate dictate. Certain customers may for a period of time have their orders expedited. This would cause production control to move their orders out of the FIFO sequence. When issued, production control hand carries the BSS for the order to the beginning of the production line at the "initial assembly" area as described in Section 2.3.

The assembly process for Desktop products was described earlier in Section 2.2. It is also shown below in Figure 3.2-7. Note that each product is built according to strict procedures. If a procedure is not available for the product being built, engineering is notified and the order is held until engineering provides the procedure.

Improving Order Fulfillment Predictability

Prioritize Build Sequence 19

NIO: Desktop Products



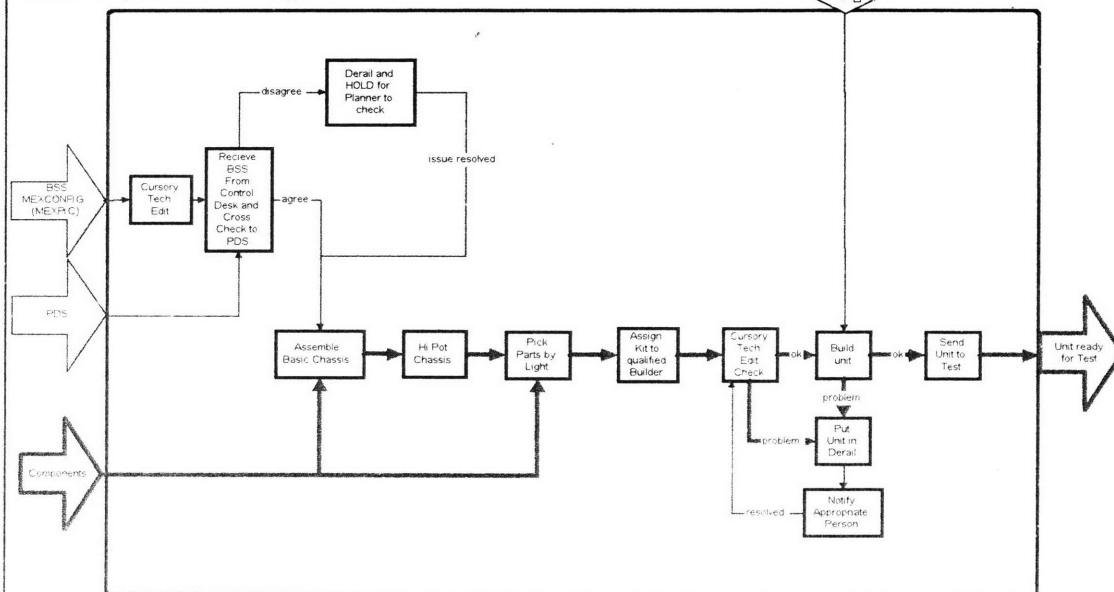
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Prioritize Build Sequence
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Figure 3.2-6: Prioritize Build Sequence

Build Product 21

NIO: Desktop Products



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Patrick Hopkins 01/15/97

Figure 3.2-7: Build Procedure

Figure 3.2-8 shows the procedure used for final testing of the product after assembly. The BSS has a barcode with the order number and product configuration coded in. After the unit being tested is placed in a test rack, this is scanned in. A computer system then determines if an automated test procedure exists for this machine. If it does, it is run immediately. If not, then one is manually generated and run. If the product passes the test, it is forwarded to packaging. If not, the unit is held until engineering can diagnose and solve the issue.

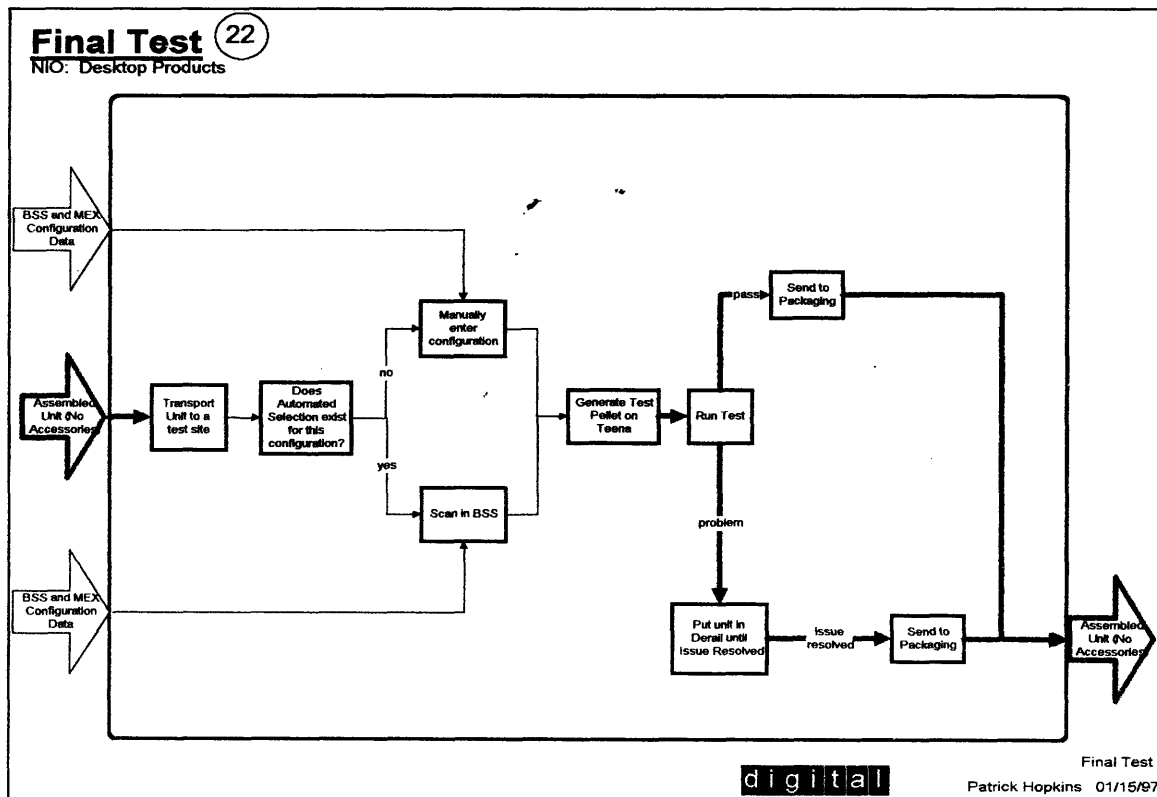


Figure 3.2-8: Final Test Procedure

After the unit passes its test, it is forwarded via rolling conveyor to the packaging and final quality check area. This procedure is shown in Figure 3.2-9. The actual product configuration is checked against the BSS. The required licenses and other paperwork are printed and placed with the unit. A final visual

inspection is done and if necessary, the unit receives touch-up paint or clean-up. The unit is then boxed-up and the accessories ordered are added. The box is then weighed and forwarded to a pre-shipping area called "Gateway".

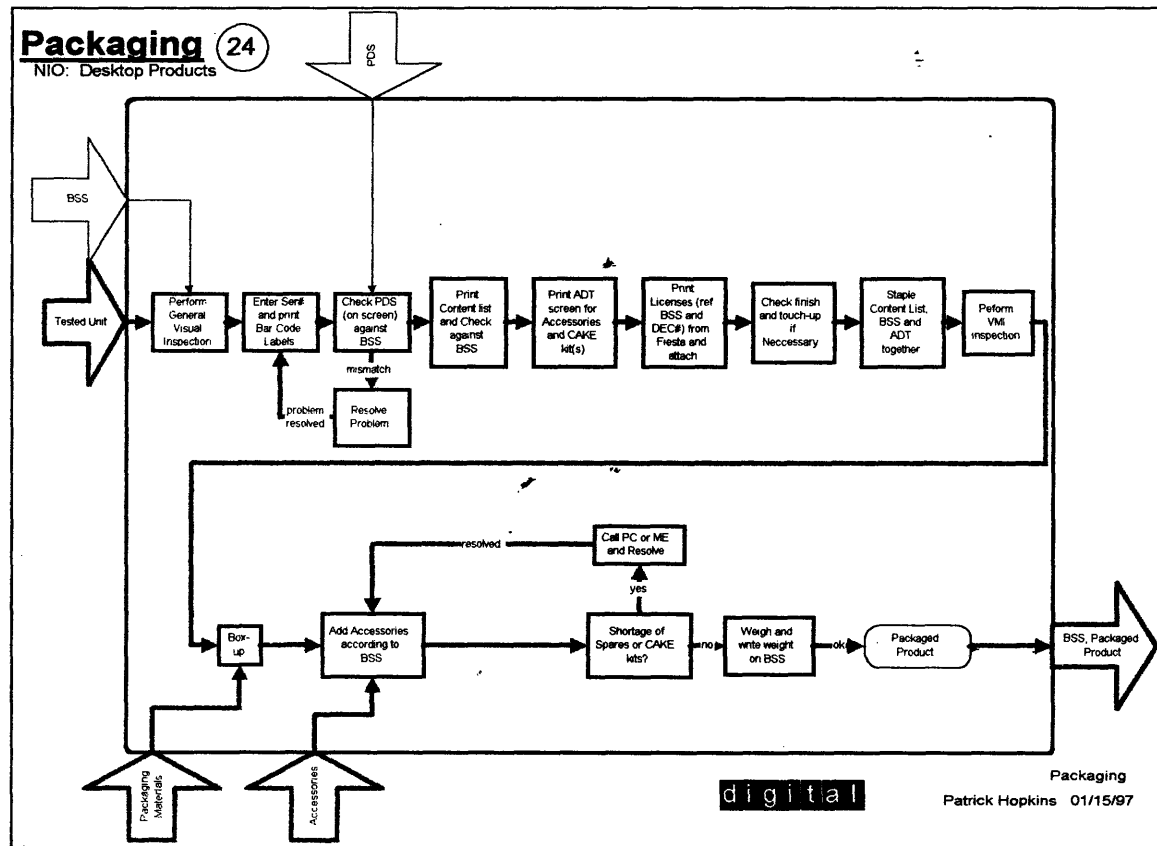


Figure 3.2-9: Packaging Procedure

The Gateway area is simply a holding area where orders are held until they are checked again for content and inventory transactions are completed. There are two people with computer terminals reading in the BSS paperwork for orders which come into the Gateway area. All of the parts used for the assembly of the order are then moved from the work in process (WIP) inventory into the finished goods inventory on the MAXIM⁹ (materials planning software) system.

⁹ MAXIM is a trademark of ASK Corporation.

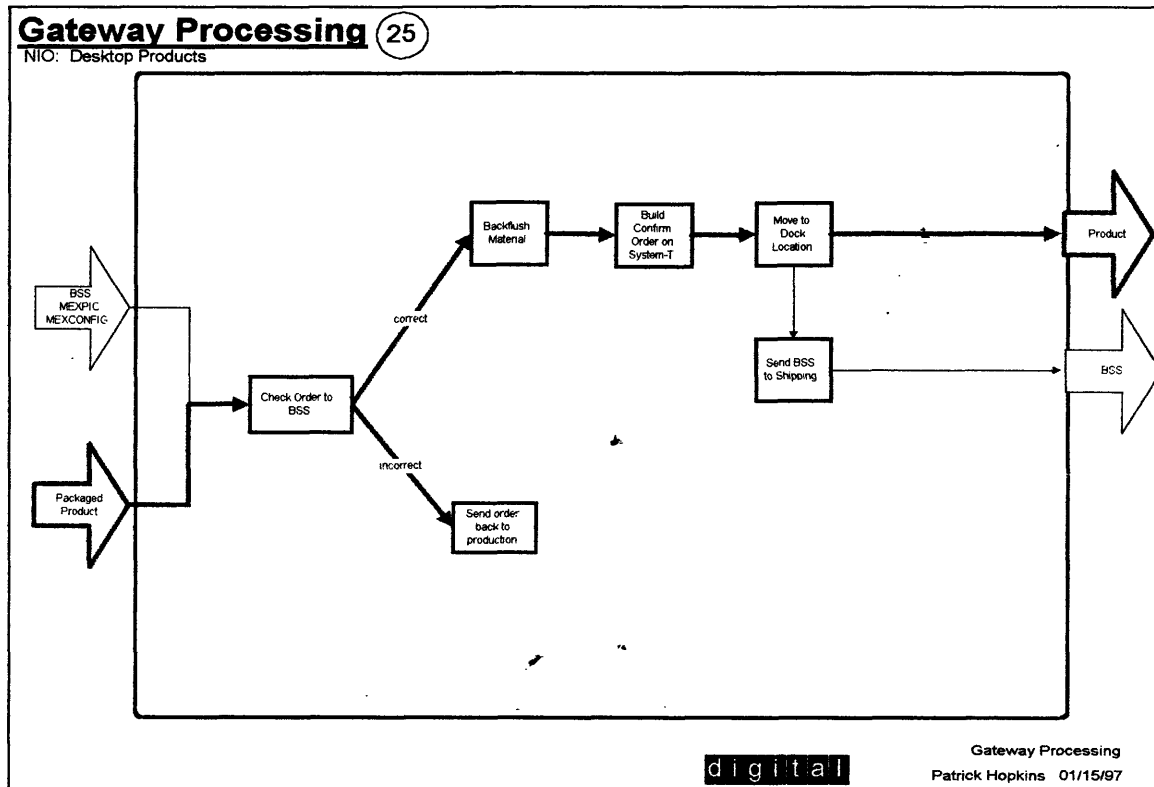


Figure 3.2-10: Gateway Procedure

Orders are held in the Gateway area until the shipping activity moves them. This shipping activity procedure is documented in Figure 3.2-10. The first step when the order is received is to create a pick sheet. This is a content list for the full order. Since all that has been created so far is the actual computer hardware and accessories, the remaining items that the customer ordered must be consolidated into a shipping unit. These items include software, optional equipment and even other workstations. After the pick sheet is printed, the shipping personnel check to see if a ship authorization has been received. The ship authorization is submitted by the Order Administration department as a final control on shipping the order. If the ship authorization is available, the order is

consolidated according to the pick sheet and shipped. If not, it is held until the paperwork is available.

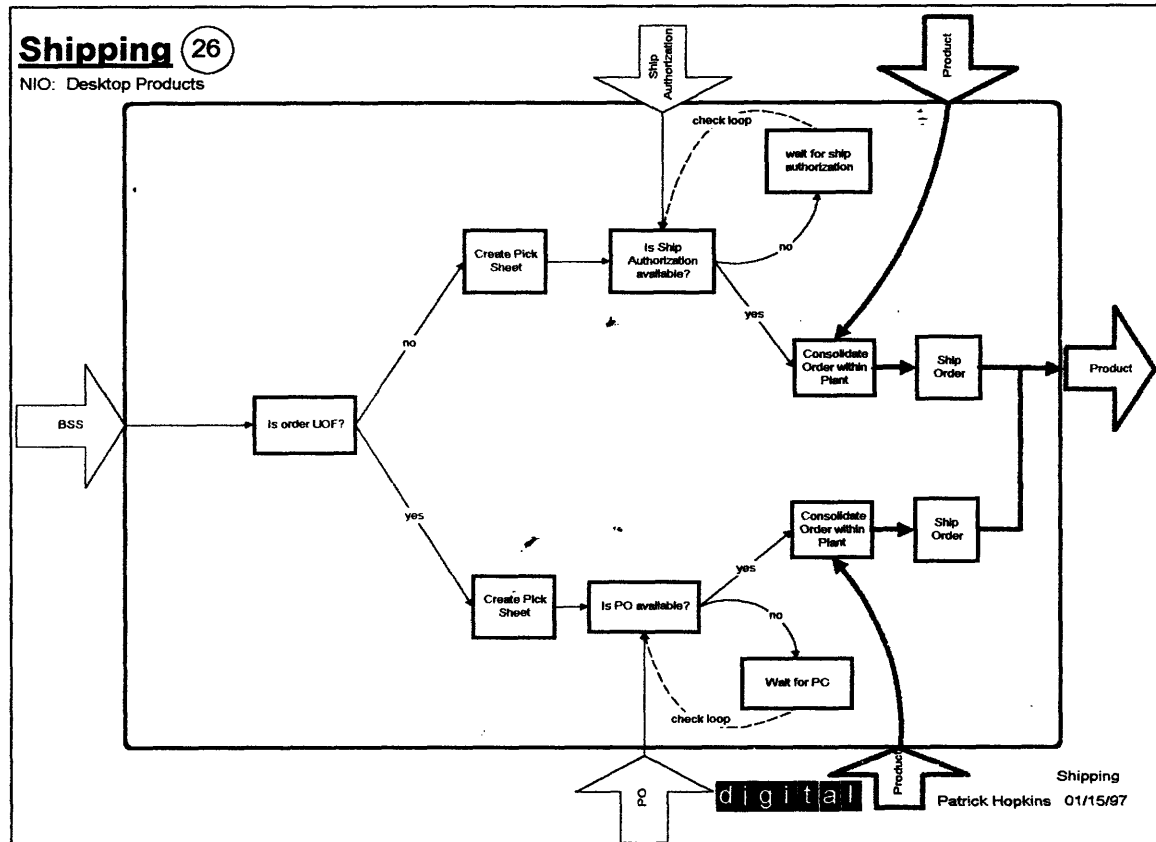


Figure 3.2-11: Shipping Procedure

At this point, the order fulfillment activity is complete.

3.3 Evaluation of Order Fulfillment Process

There are several weaknesses in the order fulfillment process. First, there is significant redundancy in the technical editing procedure for orders. Tech editing is performed twice: once at order processing and once at the Salem site. This creates an organizational problem of ownership. Since two groups on two different sites (one in Merrimack, NH and the other in Salem) are doing the same job, it becomes unclear which one has ultimate accountability for the final

product. The fact that unviable orders still reach the manufacturing floor (this is discussed in detail in Chapter Four) is indicative of the problem. These operations need to be consolidated.

Another problem with the process is that orders are scheduled for delivery to the customer without accounting for material availability. Unless material acquisition matches incoming order volumes exactly (which it does not), this practice will lead to material shortages and late orders. Material availability information needs to be used when orders are scheduled.

The "Gateway" activity is not useful. The activities performed at Gateway could easily be performed in other areas. The backflushing activity can easily be performed automatically in shipping. The order consolidation activity is already performed by shipping personnel. The finished goods should be forwarded directly to shipping and managed there. The intermediate step at Gateway only serves to slow the entire process down.

Chapter Four: Data Collection

4.1 Data Collection Method

TQM¹⁰ data collection and analysis techniques were used to better understand the problems the Desktop workstation team was experiencing in everyday operations¹¹. Other methods of data collection were not considered.

4.2 Description of Process

The data collection effort consisted of three phases. The first step was to work with the Desktop cross-functional manufacturing team (also called the "Desktop workcell team") to determine an exhaustive list of causes for customer orders to not be fulfilled on time. The second step was to collect data for eight weeks using this list as a guide. Finally, the data was then organized and analyzed in order to diagnose and fix problem areas. This data analysis also provided a source of real data for the later developed simulation model to be tuned and tested.

Several meetings were conducted with Desktop team members from Order Administration, Material Acquisition and Purchasing, Production Control, Production, Gateway and Shipping. In each meeting, an exhaustive list of late order causes was developed. The full list is shown below in Table 4.2-1.

Description
BSS never issued
BSS lost on floor
BSS found to be dirty: regenerate
BSS misfiled behind late orders

¹⁰ Shoji Shiba et al. *A New American TQM*. (Portland, Oregon: Productivity Press. 1993). p. 73.

¹¹ This activity was conducted in conjunction with Thomas Jacob, another LFM intern working in this same DEC facility.

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dirty order
change order
canceled line item on order
wrong configuration
pullin (material shortage)
pullin (capacity shortage)
BOM changes
BOM inaccuracy
wrong PEN(etration) rate
ATP lead-time offset not adequate
forecast (IFP) inaccuracy
vendor supply doesn't support current plan
ATP set to lead time without vendor support
stock status inaccurate
scheduling in excess of ATP
no delivery against commits
commits don't cover requirements
management reallocation of stage 1 parts
POM partner material not available
commits not timely
bad parts in door
purges and ECOs
stock status inaccuracy:SY2, DT, DS
inadequate load balancing against material and capacity
unbalanced resource allocation among work cells
process failure / test failure
repair required on order
production data system (PDS) problem
production systems or applications availability
date sequence for build not followed
coverage difficulty
absenteeism and vacations
recon utilization

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queuing delays (unknown cause)
unknown cause

Table 4.2-1: Initial List of Possible Causes for Late Orders¹²

In later meetings, this list was broken down into nine concise categories. Each reason was assigned a code name linking it to a general category. For example: the problems associated with the build paperwork (BSS) were brought under the category "BSS". The four individual codes are then BSS1 through BSS4.

Category	Code	Description
No BSS	<i>BSS1</i>	never issued
	<i>BSS2</i>	lost on floor
	<i>BSS3</i>	found to be dirty: regenerate
	<i>BSS4</i>	misfiled behind late orders
Tech Edit	<i>TE1</i>	dirty order
	<i>TE2</i>	change order
	<i>TE3</i>	canceled line item
	<i>TE4</i>	wrong configuration
Pull-In	<i>PI1</i>	pullin (material shortage)
	<i>PI2</i>	pullin (capacity shortage)
Materials	<i>M1</i>	BOM changes
	<i>M2</i>	BOM inaccuracy
	<i>M3</i>	wrong PEN rate
	<i>M4</i>	ATP lead-time offset not adequate
	<i>M5</i>	forecast (IFP) inaccuracy
	<i>M6</i>	pipeline doesn't support current plan
	<i>M7</i>	ATP set to lead time without pipeline

¹² This list is shown for the purpose of demonstrating the methods used, not to enumerate the specific problems faced. For this reason, some unexplained abbreviations and terminology are used.

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	<i>M8</i>	stock status inaccurate
	<i>M9</i>	scheduling in excess of ATP
Supply	<i>S1</i>	no delivery against commits
	<i>S2</i>	commits don't cover requirements
	<i>S3</i>	management reallocation of stage 1 parts
	<i>S4</i>	POM partner material not available
	<i>S5</i>	commits not timely
Quality	<i>Q1</i>	bad parts in door
	<i>Q2</i>	purges and ECOs
Production	<i>PC1</i>	stock status inaccuracy:SY2, DT, DS
Control	<i>PC2</i>	inadequate load balancing against material and capacity
	<i>PC3</i>	unbalanced resource allocation among work cells
Production	<i>P1</i>	process failure / test failure
	<i>P2</i>	repair
	<i>P3</i>	production data system (PDS) problem
	<i>P4</i>	production systems or applications availability
	<i>P5</i>	date sequence for build not followed
	<i>P6</i>	coverage difficulty
	<i>P7</i>	absenteeism and vacations
	<i>P8</i>	recon utilization
	<i>P9</i>	queuing delays (unknown cause)
Unknown	<i>?</i>	unknown cause

Table 4.2-2: Categorized Late Order Cause List¹³

Using this list of reason codes as a guide, the Desktop workcell team would assign a code for each of the orders which were scheduled to be shipped during the previous day but were not. Most of the time, the reason could be determined

¹³ This list is shown for the purpose of demonstrating the methods used, not to enumerate the specific problems faced. For this reason, some unexplained abbreviations and terminology are used.

at the morning meeting. Occasionally, further investigation was required on the production floor or in the Order Administration area. Weekly reports on late order causes were fed back to the workcell team. This helped them to more effectively determine where the problems were occurring.

The final step was to compile the collected data. A pareto chart was created for all of the data collected during the first quarter of fiscal year 97. This pareto chart is shown below in Figure 4.2-1. The major observation made was that material supply problems were the major cause of late orders.

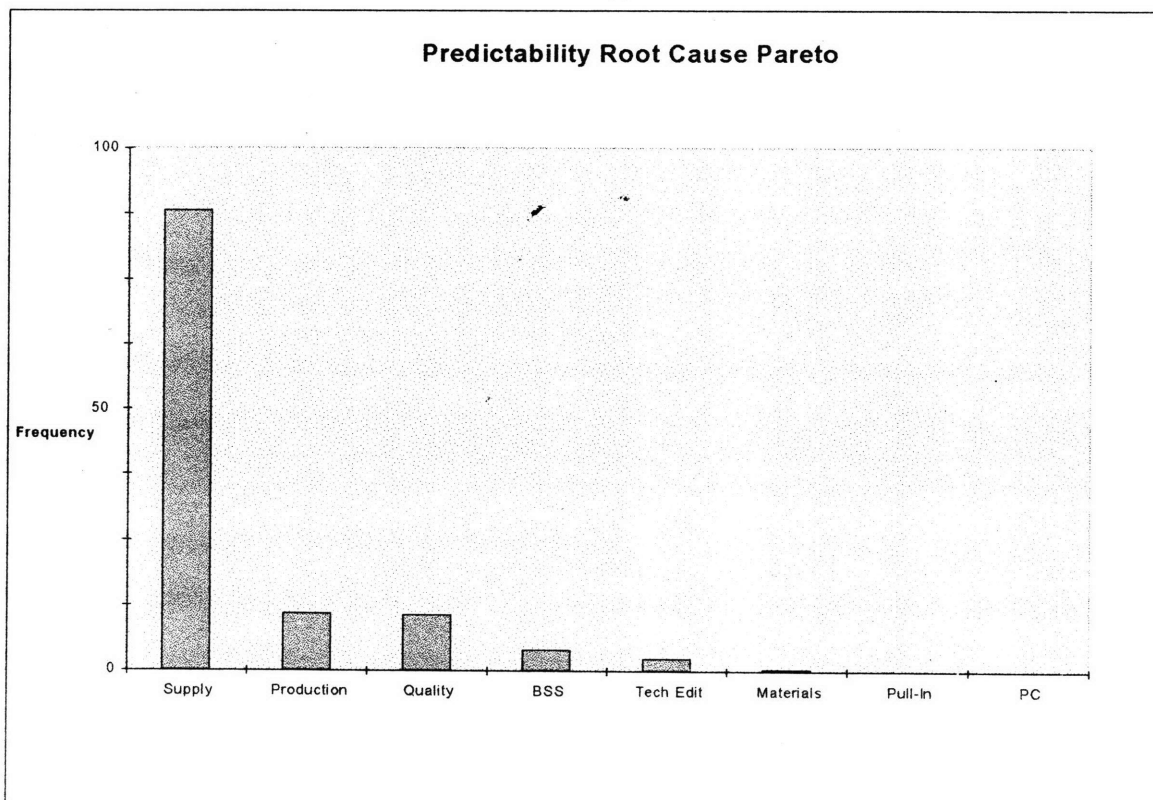


Figure 4.2-1: Pareto of Late Order Causes¹⁴

Another use for this data will be when the simulation model is built and failure rates for each step of the process will be assigned. If the number of

¹⁴ Quantities shown in this figure are not based on actual data and are for illustrative purposes only.

orders which failed in each general category is divided by the total number of orders processed, the failure rate for each part of the process is calculated. A summary of these calculations is shown below in Table 4.2-3.

Category	% Failure Rate
Supply	26.8
Production	3.3
Quality	3.2
BSS	1.2
Tech Edit	0.7
Materials	0.1
Pull-In	0.0
PC	0.0

Table 4.2-3: Failure Rates for Each Area¹⁵

4.3 Evaluation of Process

One weakness of this method of data collection is that the problems which occur early on in the order fulfillment cycle tend to mask other problems which occur downstream. This happens because once we found one reason for the lateness of an order, we did not track that order any longer. If that same order experienced problems later in its cycle, they would be missed. This does not render the data useless, but this factor must be considered when this data is used for any other purpose.

In hind-sight, we should have tracked all orders throughout their lifetimes, but we could not afford the time to collect data again for a full quarter. The ideal situation would have been to track every problem associated with every order which would cause it to be late. This would require quite a bit of time for each individual involved in the order processing procedure. This was not a

¹⁵ Calculations based on actual data collected by author. Used with permission of DEC.

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reasonable expectation given the job responsibilities that each person had.

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Chapter Five: Simulation Model

5.1 Overview

The purpose of the mapping and data collection phases of the project is really to support the construction of an accurate simulation model. The goal of the project is to analyze the Salem site using a simulation model. This places equal importance on the mapping, data collection and model construction phases. So while Chapter Four seems to describe the most important work in the project, it cannot stand alone without the other two.

5.2 Tools Used

The Witness¹⁶ simulation software sold by AT&T Istel was chosen to be used for the simulation modeling of the Salem site. Witness allows almost any process to be modeled by defining the individual activities that make up a process, as well as the time required to complete each activity. Buffers can be placed between each activity and decision rules govern the flow of the activity. The other software package considered for use was Vensim¹⁷. Vensim is a system dynamics modeling package sold by Vanata Systems.

Witness was chosen over Vensim for several reasons. First, Witness is a discrete time based simulation tool, where Vensim, like other system dynamics software is designed for continuous flow applications. Witness allows easy linkage of activities to discrete periods of time. Second, Witness allows almost limitless decision rules at each stage. Vensim is designed such that mathematical relationships between "stocks" govern the "flow" to the next stock.

¹⁶ Witness, version 7.30. Developed and sold by AT&T Istel. Witness is a trademark of AT&T Istel.

¹⁷ Vensim, version 1.64-2. Developed and sold by Venata Systems, Inc. Vensim is a trademark of Venata Systems, Inc.

This can encumber the user if there are multiple flow paths available from a particular point.

Witness also has a very good visual interface which shows material flowing from activity to activity and stock building up at bottleneck points. This is helpful in the usage of the model to demonstrate to others. It also aids the user in developing an intuition for what is happening.

Another strong point of Witness is an almost unlimited allowance for activities. While many packages limit the user to a certain number of activities, Witness allows enough activities for even the most complex operation. This was very important for this application for two reasons. First, the enterprise being modeled is very large and has multiple levels. Second, the required complexity for the model was not known at the outset, so having virtually no constraints on size alleviates the concern of investing large amounts of time, then finding a limit in the capacity of the tool and having to start over.

Finally, the software was readily available at the site where the work was being done. Experienced users were also available for consultation when needed.

5.3 Description of Witness

The Witness model for the Salem site is a combination of three types of elements:

1. **Parts:** Generic term describing something that flows through a process. An example is a printed circuit board or an order.
2. **Activities:** Defines a distinct activity that takes place on some part. An example is soldering a connector onto a printed circuit board.
3. **Buffers:** Holding area for parts. An example is the in box for the order scheduler.

A diagram of a simple Witness model is shown below in Figure 5.3-1. The model is of a two-step operation: cutting and sanding a wooden block.

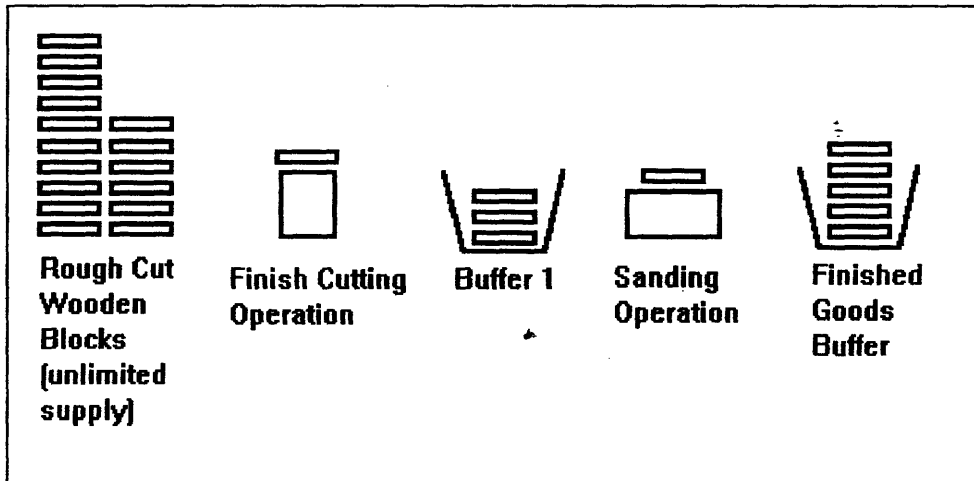


Figure 5.3-1: Block Cutting and Sanding Operation

As shown, there is an unlimited supply of raw materials. These are the rough-cut blocks of wood. These blocks of wood represent the part being operated on. The part is further defined by its attributes. Attributes are uniquely defined for each type of part and can be assigned a different value for each individual part. For instance, an attribute for the blocks of wood might be cracked or not cracked.

The first activity, finish cutting, draws off of this supply whenever the operator is ready. The finish cutting activity is further defined by two parameters:

1. Cycle time: This is some definition of how long it takes to accomplish the task at hand. This can be defined by a constant or a wide variety of randomly distributed values.

2. Routing rules: These rules determine what the operator does with the part either before or after he is done. For instance, if the wood is cracked, he may discard it before the operation is performed.

The buffer which follows the finish cutting activity is defined by two parameters: maximum capacity and queuing rules. The queue rules define what order the parts leave the buffer. First-in-first-out (FIFO) or last-in-first-out (LIFO) are two options available to the user.

The final activity, sanding, is defined in the same way as the first. When the parts are done, they are moved to a finished goods buffer. As with the real world, if a buffer is full, the activity behind it is blocked and will remain blocked until the buffer is no longer full.

5.4 Description of Model of Salem Facility

The simulation model for the Salem site was built in the same manner as the simple model described in the previous section. The flow of work was already defined as a set of connected tasks by the flowcharting described in Chapter Three. These tasks each have some sort of buffer between them. In the case of administrative tasks, the buffer was usually an in-box. For shop-floor activities, the buffer might be a holding area or a section of conveyor with a limited number of slots.

The time required for each task was determined in the process documentation phase and assigned to each task. The size of each buffer was determined by approximation given the size of the actual area. Decision and routing rules were adapted from the process documents also. The graphical representation of the model is shown in Figure 5.4-1.

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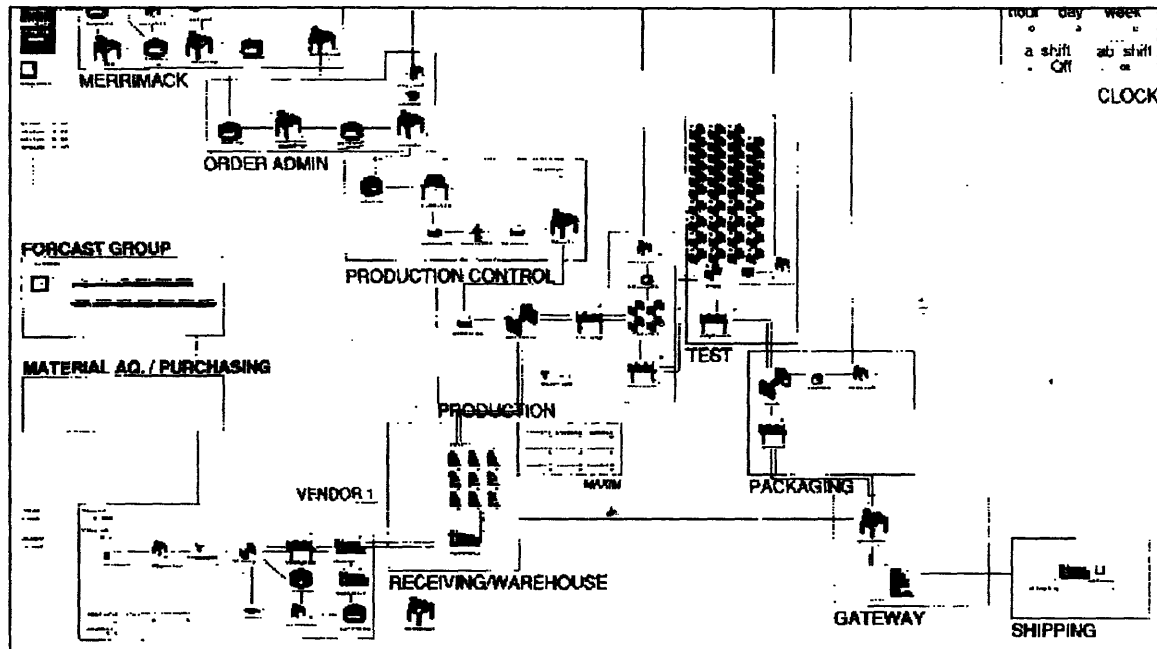


Figure 5.4-1: Witness Model of Salem Process

As with the process documentation, some attempt was made to show the tasks in the order they are actually done and the functional department boundaries where applicable. The groups are listed below in the order in which they occur in the simulation:

1. Order Processing
2. Order Administration
3. Production Control
4. Production
5. Test
6. Packaging
7. Gateway
8. Shipping

Other concurrent activities are conducted by the following groups:

1. Forecast Group
2. Material Acquisition and Purchasing
3. Vendors (nine of them)
4. Receiving

The specifics of the operation of each of these groups is described in Chapter Three.

Some approximations were made to make the model more manageable. Only one product was modeled, which was a Desktop product. The configuration of the product was simplified into nine critical components. There were therefore nine vendors. This is a large enough number of vendors to represent the randomness of the given supplier base, while greatly simplifying the model.

Vendors were assumed to build off of orders placed by DEC's purchasing group. A certain percentage of these materials were delivered on time, the rest one week late. 86% of the materials were delivered on time. This is based on a study done by Thomas Jacob¹⁸.

5.5 Proposed Changes to be Modeled

There were three major improvements which were modeled using the Witness simulation model. They were determined during the course of the process mapping and data collection phases of the project. They are a combination of suggestions made by DEC workers, management and the author. They are:

¹⁸ Thomas Jacob, LFM intern at DEC. study on vendor performance (untitled).

1. Improved Tech Edit Procedures
2. Schedule According to ATP (Available to Promise) Report
3. Schedule According to STAS (Schedule to Availability)

5.5.1 Improved Tech Edit Procedures

The improved tech edit process was modeled as an improvement in the effectiveness of the two tech edit phases, which occur in Order Processing and then in Order Administration. The present levels of effectiveness for the two edit phases are 80% and 95% respectively.¹⁹ An improved system would increase these numbers to 98% effectiveness for both phases. This would be accomplished through the implementation of a more sophisticated software driven expert system to check the feasibility of each order. This would be installed at both tech edit phases. This seems reasonable, since the Order Administration tech edit is already 95% effective with an antiquated system and the Order Processing group presently uses no computer system for checking orders.

5.5.2 Scheduling To ATP Report

Scheduling according to the Available to Promise (ATP) report would involve using a report which already exists at DEC. The "available to promise" report is compiled daily by the Materials Acquisition group as a service to the Order Administration group. The report provides information about how many units were planned for and how many units have been promised for each week of the quarter. It looks out over a 13 week horizon. A separate report is generated for each CPU speed within each product. A printed copy of this report is distributed to each scheduler at the beginning of each day.

¹⁹ Based on interviews with order administration and production personnel.

Presently, the Materials Acquisition group produces and distributes this report, but it is not used by the scheduling group which is presently scheduling according to leadtime.

There are two significant weakness of this report. First, it is not realtime. Since it is only compiled and distributed daily, its information is often 24 hours old. This causes overscheduling when more orders come in on a given day for a product than were slotted at the beginning of the day. This mistake can be accounted for at the end of the day, but the customer has already been promised the order and it will probably not be delivered on time. The second weakness of the ATP report is that it assumes that vendors will deliver all of their orders as promised on time. This is of course not realistic. Once again, the scheduler promises a product which cannot be delivered on time.

5.5.3 Scheduling According to STAS

The third and final proposed change involves the use of Schedule To Availability System (STAS). This is a proposed system described further in Chapter Six. STAS is very similar to ATP, only it alleviates the two major weaknesses of the system. It is realtime because it uses an interactive database, shared by all of the schedulers. It also uses real material availability data rather than vendor promises. For more details on STAS, see Chapter Six.

5.6 Description of Simulation Runs

Four different cases were tested using the Witness model:

1. Baseline
2. Improved Tech Edit Procedures
3. Schedule According to ATP (Available to Promise) Report
4. Schedule According to STAS (Schedule to Availability)

Each of the four was tested under nine different conditions. The variables within each of the nine conditions were actual sales volume for the product and sales skew during the quarter. Three different sales volumes and three different skews were tested giving a total of nine possible combinations.

Quarterly sales for the given product were forecast at 2500.²⁰ Sales were expected to be skewed as shown in Figure 5.6-1. This multi-step skew assumes 12% of the sales in the first four weeks, 32% in the second four and 56% in the last four weeks. This is a typical sales skew for the company, based on sales history.²¹

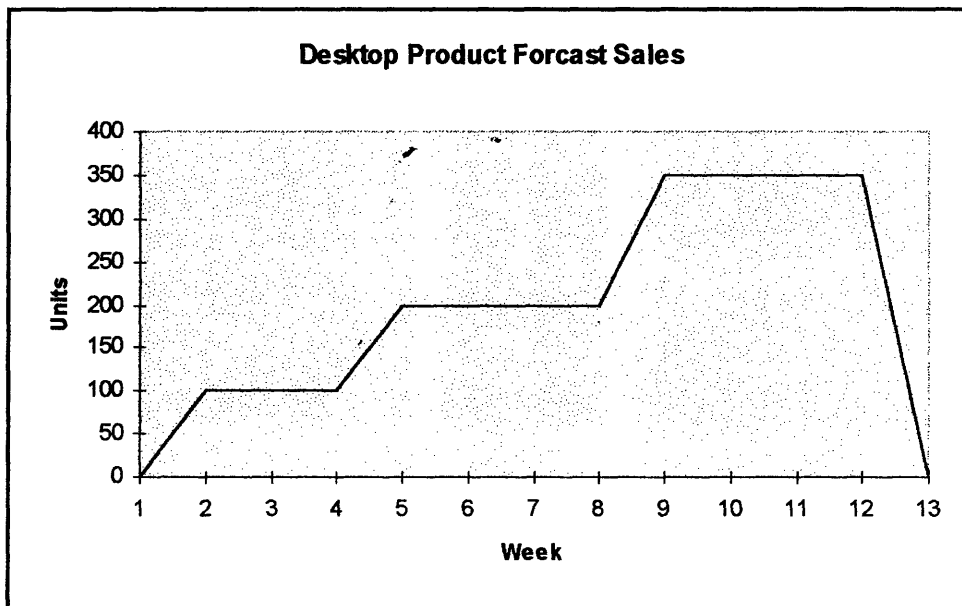


Figure 5.6-1: Forecast Sales for Desktop Product

It would not be an adequate test of any system to assume that sales occurred just as expected. In fact, the robustness of the system to sales which are not as predicted is an excellent indicator of how well the system will actually

²⁰ The sales volumes described in this chapter are not actual sales volumes for DEC. They are used for illustrative purposes only.

²¹ Based on interviews with materials supply personnel.

perform. Therefore, the nine test cases were devised. Figures 5.6-2, 5.6-3 and 5.6-4 show the nine test sales curves used to drive the model. Each figure represents three different sales levels (50%, 100% and 200% of forecast) for one of three different types of sales skew: typical, flat (none) and reverse.

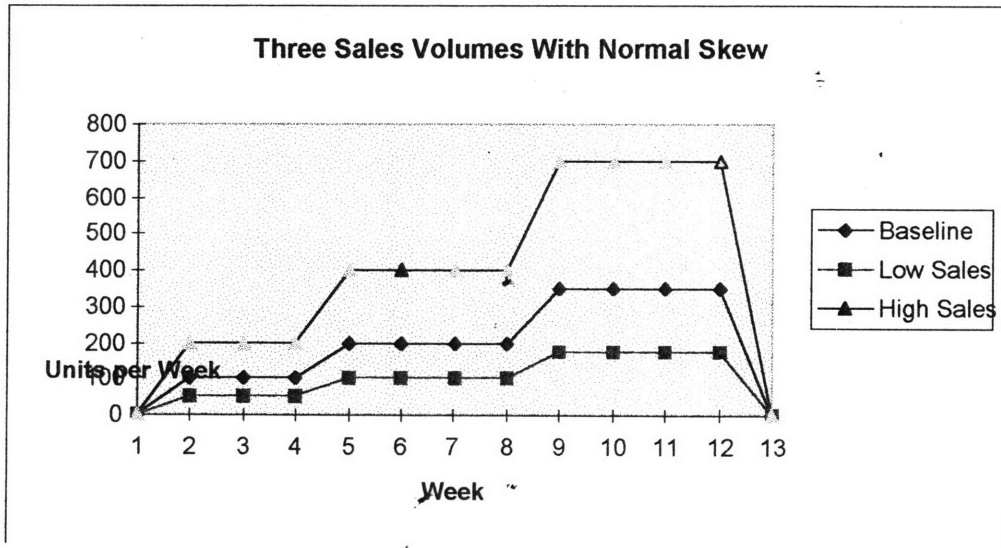


Figure 5.6-2: Typical Skew With Three Levels of Sales Volume

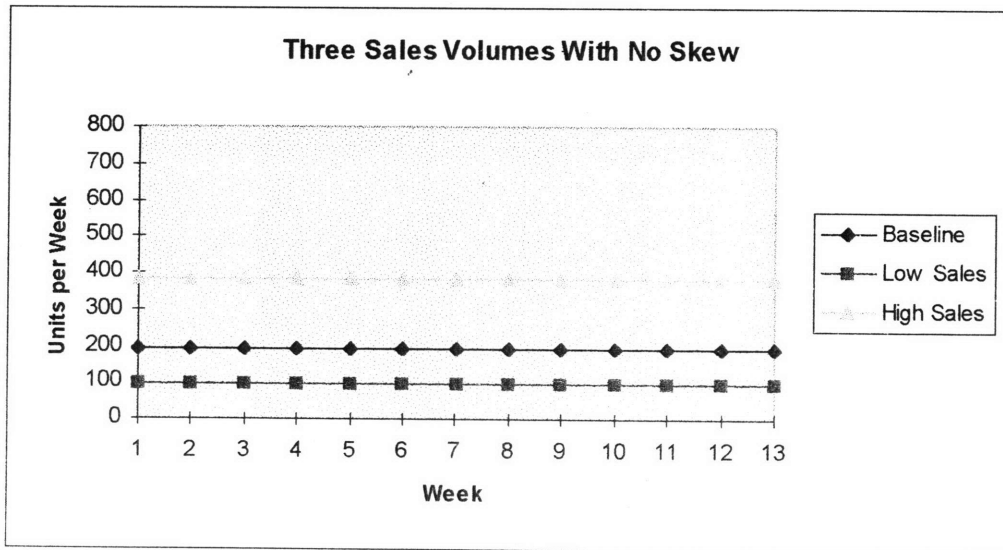


Figure 5.6-3: No Skew With Three Levels of Sales Volume

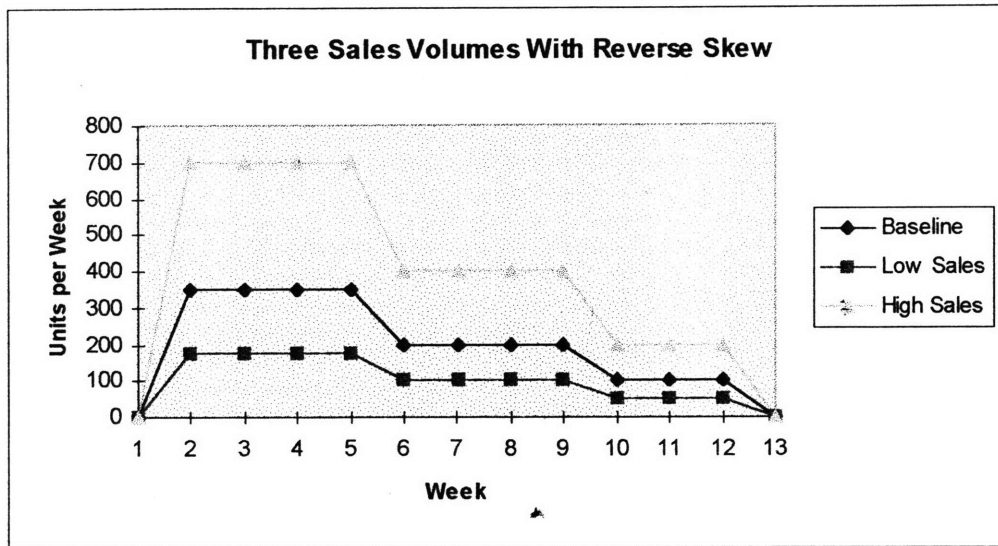


Figure 5.6-2: Reverse Skew With Three Levels of Sales Volume

Each model run represented one quarter's activity for the plant. One model run was made for each of these nine cases and the order fulfillment predictability was determined weekly and for the quarter.

5.7 Results of Model Runs

The key output of the simulations was the predictability across all nine cases. The performance of the baseline system is shown for all nine test cases in Figure 5.7-1.

In terms of volume of actual sales, the baseline system performs well when volumes are half what was planned for, no matter what the skew. This is due to the fact that there is always plenty of material available throughout the quarter in these cases. It also indicates that the majority of the late orders are due to the scheduler scheduling an order for which, for one reason or another, at least one component is not available when it reaches production.

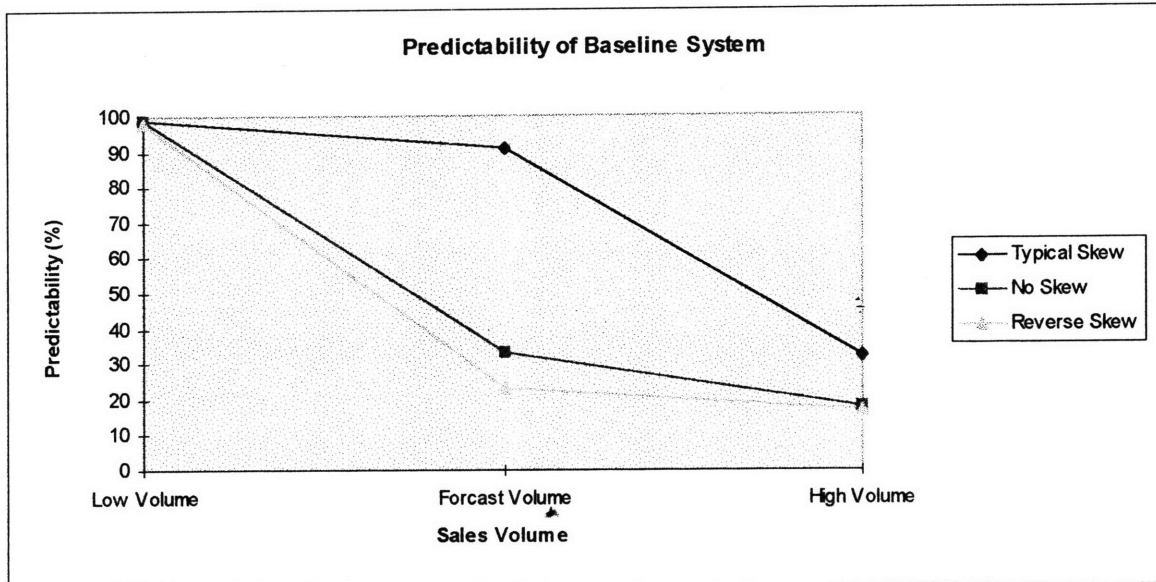


Figure 5.7-1: Predictability of Baseline System

Predictability falls off when volumes are as forecast or high. The least fall-off occurs when the actual sales follow the typical skew. More severe loss of predictability occurs when the sales follow a flat or reverse skew. Since more orders occur early in the quarter than expected in these two cases, this again points to material availability as the major problem with late orders. The overall average of predictability with the baseline system is 57%.

The predictability of the system simulated with improved tech edit procedures is shown in Figure 5.7-2. The predictability of the system with improved tech edit procedures is very similar to the baseline performance. The average predictability is 58%. This is not a significant improvement.

The predictability of the system with the ATP report used for scheduling is shown in Figure 5.7-3. As with improving the tech edit procedures, there was not a marked improvement in the predictability of the system when orders were scheduled according to the ATP report. The overall average predictability is 61%.

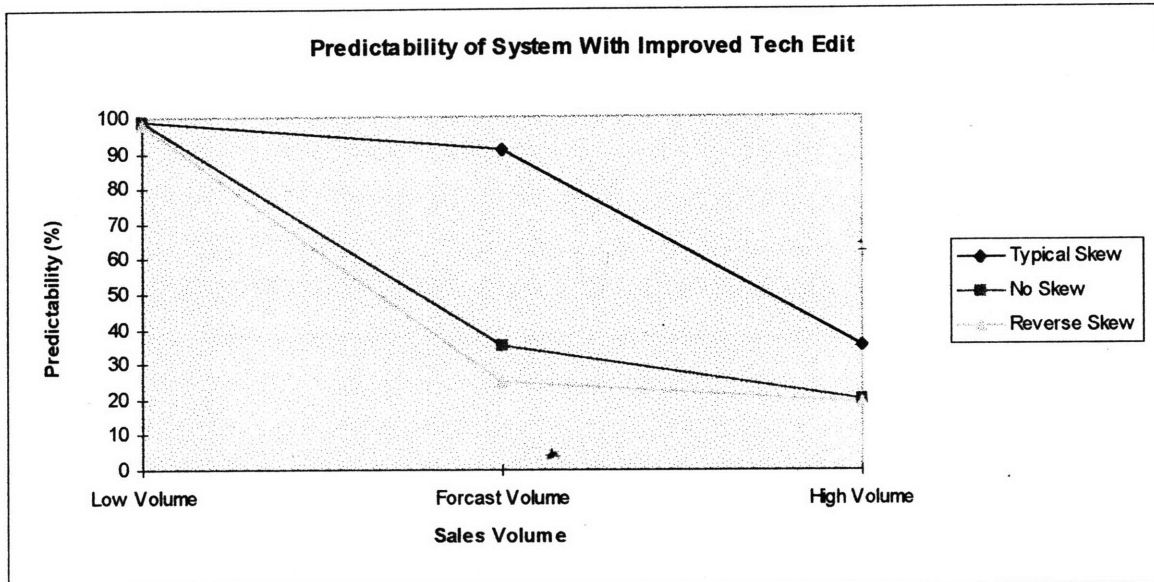


Figure 5.7-2: Predictability of System with Improved Tech Edit Procedures

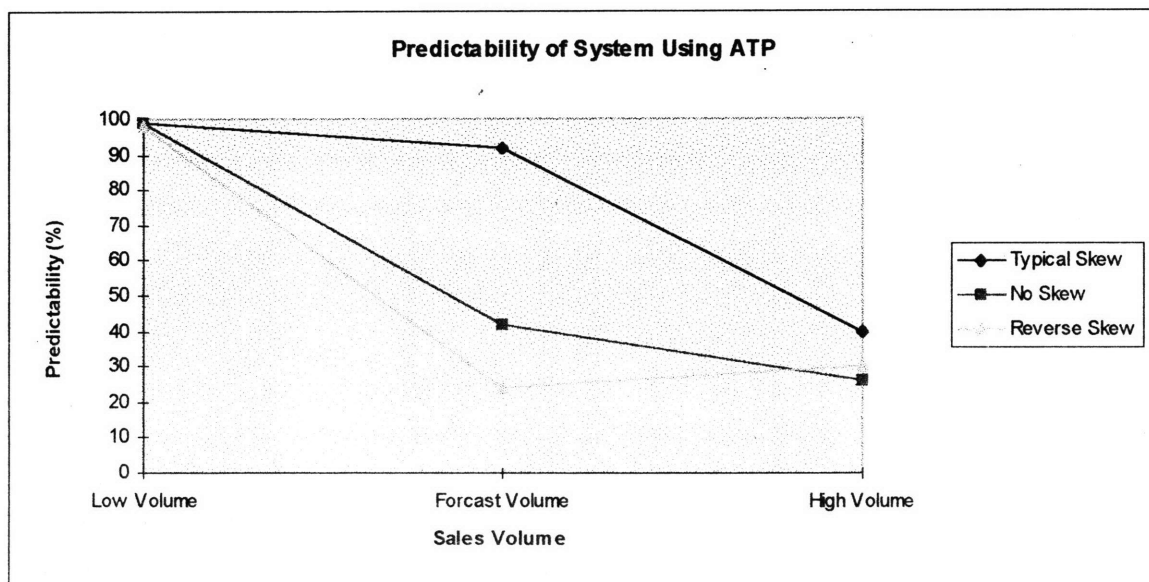


Figure 5.7-3: Predictability of System Using ATP Report for Scheduling

The predictability of the system across all nine test cases when the orders were scheduled to material availability is shown in Figure 5.7-4.

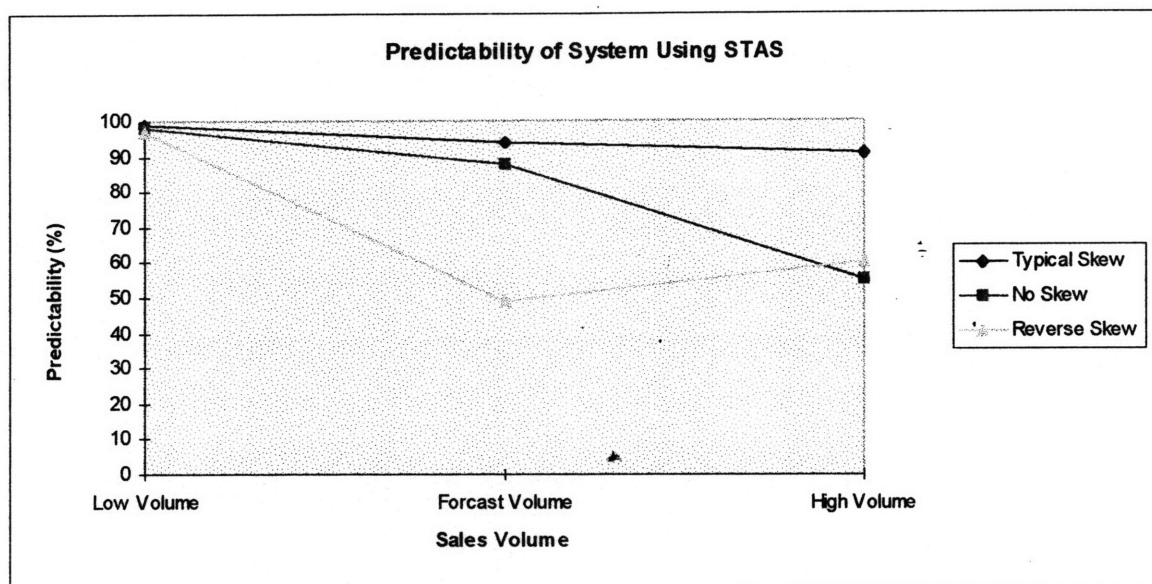


Figure 5.7-4: Predictability When Orders are Scheduled to Material Availability

Significant improvement is shown across all test situations. The average predictability was 81%, 24 percentage points higher than with the baseline system. This system is not perfect, however. When sales are higher than expected the predictability suffers. This effect is worsened when the skew of the sales is also not as expected (either flat or reversed).

Overall, it appears that the tech edit and STAS methods for improvement show promise given the results of the simulations.

Chapter Six: Predictability Improvement Proposal

6.1 Introduction

It has been shown by the simulations performed in the previous chapter that a major source of improvement in predictability performance would be the institution of a system where orders were scheduled according to actual material availability. This type of realtime information sharing is advocated in much of the operations management literature (e.g. Hayes et al).²² The purpose of this chapter is to define such a system such that it can be implemented by information systems and order administration personnel.

6.2 Requirements of Proposed System

A simple picture of the tasks required to fulfill and order at NIO is shown below in solid lines in Figure 6.2-1. As described in Chapter Three, orders are presently scheduled according to standard lead-times, determined by corporate. The proposed system (labeled "STAS") is shown in dashed lines. The goal of the Schedule To Availability System is to provide the scheduler with real-time information about material availability while he is committing product to the customer. The tool should pool information about:

1. present inventory levels
2. present vendor commits
3. vendor delivery performance
4. present number of unfulfilled orders

²² Robert H. Hayes et al, Dynamic Manufacturing. (New York: The Free Press, 1988), p. 185.

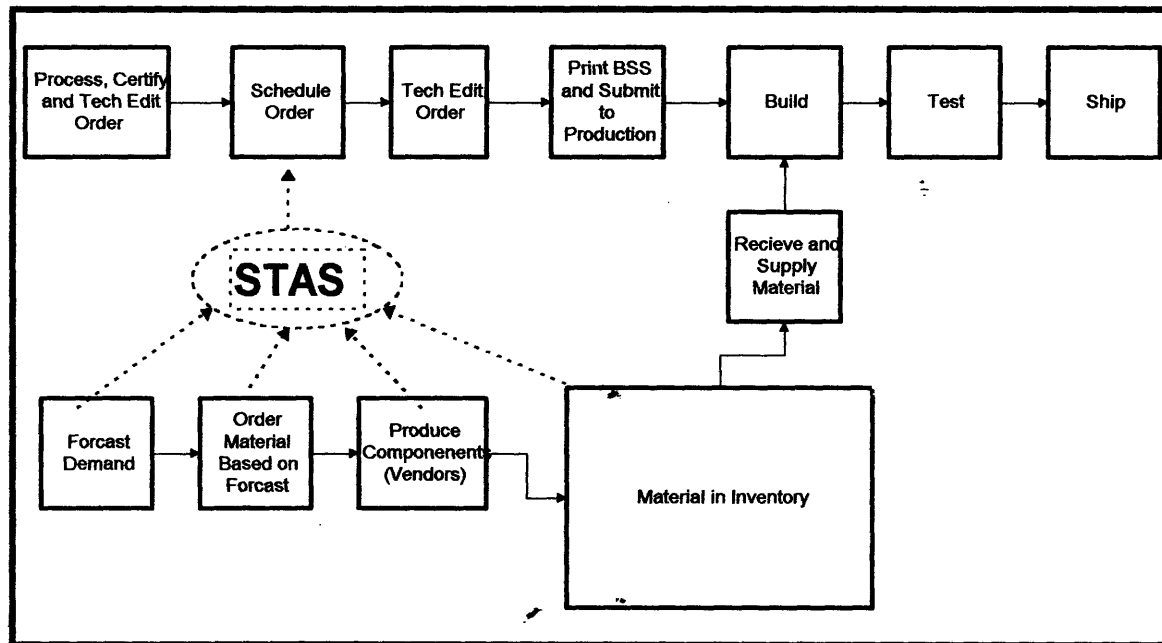


Figure 6.2-1: Present Order Fulfillment Process Steps (Simplified)

With this information provided to the "schedule order" function, more accurate promises can be made to the customer. The system that provides this information to the scheduler should be real-time and be instantaneously updated when new orders are scheduled. This will avoid the situation where two or more orders are scheduled in the same "slot" simply because one scheduler was not aware of what another was doing. The information system provides this communication link automatically.

6.3 Detailed Description of Tool

A more detailed description of the workings of the proposed information system is given below. The description will begin at the user (scheduler) interface and move "backwards" into the information system itself.

As shown in Figure 6.2-1, the proposed information system would link actual material availability information to a real-time availability report used by scheduling personnel. A simple idea of what the interface with the scheduler would look like is shown below in Figure 6.3-1.

Available Slots for Product X	
Week 1	0
Week 2	0
Week 3	13
Week 4	200
Week 5	200
Week 6	200
Week 7	300
Week 8	300
Week 9	300
Week 10	300
Week 11	400
Week 12	400
Week 13	400

Figure 6.3-1: Simplified User Interface

One of these charts would be generated for each product configuration (i.e. each top level salable part number) at the prompt of the scheduler. The scheduler would simply look at this table and determine which week he could promise the order for. Present convention in the scheduling activity is to promise the order shipped at the end of a week. So, supposing we are in week 1, if a scheduler received an order for 10 units of Product X, using the information in Figure 6.3-1 he would promise the order delivered in week 3. He

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would then submit the order to the order tracking system with a promised ship date (PSD) of the end of week 3.

The table itself is generated by doing some simple math on available information. When prompted to generate a table for Product X, the system would use the bill of materials (BOM) for the salable part number and query available databases and determine:

1. The number of full kits (kit meaning a set of materials required to build a certain product) available for use in all on-site warehouses.
2. The number of full kits of material planned to be received according to present POs in future weeks.
3. The average vendor predictability for the parts in Product X.
4. The number of unkitted (unkitted meaning scheduled but not having any material pulled yet) orders for Product X presently in MAXIM.

All of this information is available on MAXIM.

Using this data, the system would generate the table in Figure 6.3-1 as follows:

Step 1: Calculate the number of units of Product X which could be built in the following week:

$$\text{availability} = (\# \text{ of full kits}) - (\# \text{ of unkitted orders})$$

If this number is negative then it would be rolled into the following week.

Step 2: Calculate the *expected* material availability for the following weeks. For each week the following calculation would be done:

$$\text{availability} = (\text{avg. vendor predictability}) * (\# \text{ of full kits ordered})$$

This allows the scheduler to schedule according to expected material availability.

Since this table would be generated whenever an order for a product of this type was being scheduled, the most current data would always be used when scheduling an order. In order for this system to work properly, the orders must be fulfilled by production in a FIFO according to the assigned promised ship date. If this system is implemented across an entire product line, the promising results demonstrated in the modeling activity could be achieved.

Chapter Seven: Recommendations for Future Work

7.1 Implementation of Proposed System

The most important future work in this area is to implement a system similar to the one recommended in Chapter Six and begin scheduling orders according to material availability. Based on this study, this is by far the area in which the greatest improvements can be realized. There are two groups of hurdles which must be overcome while implementing this system: technical and organizational.

7.1.1 Technical Issues

There are three major technical issues involved in the implementation of a STAS-like system: developing the software itself, getting the necessary equipment in front of each user and assuring the accuracy of the data being used.

The software itself has already been developed. The Ayr DEC facility has already developed a system which works with MAXIM to access material availability information and provide it to the scheduling activity. The installation of such a system is fairly trivial. However, some adjustments will certainly have to be made for the Salem environment and this may take a short period of time.

The necessary equipment for this system to work is either a PC or a workstation provided for each order scheduling person. These systems are already in place and used on a daily basis to track order and customer information.

Warehouse stock level data is readily available on resident databases. The integrity of this data is unknown and must be evaluated. This is important as the order promise date will be directly based on the accuracy of this data. As part of the implementation of this system, the integrity of the stock data should

be determined. If it is inadequate, it should be improved. If it appears adequate then a careful monitoring and checking system should be implemented in order to police the accuracy of the data on a continual basis.

7.1.2 Organizational Issues and Proposed Solutions

The technical issues involved in the implementation of this project are truly trivial and in fact have largely already been overcome. What will cripple the implementation is organizational issues.

The NIO organization is heavily functionally organized. This presents a challenge to the implementation of a system such as STAS, since the Materials organization will be supplying this information to the Order Administration group. It will be key that the group of people implementing this system is a cross-functional team of people from Materials, Order Administration and Information Systems.

The major objective of management in this situation should be to create a sense of common ownership and trust between the Materials and Order Administration groups. This can be accomplished by tying the incentives of the group members and first level managers to the successful implementation of such a system. This creates a sense of shared accountability among the team members. It is important that the effort not be labeled a "Materials Organization Effort" or an "Order Administration Effort". It must be shared.

Another key to bringing the Materials and Order Administration organizations together effectively is to have the implementation overseen by the "product family managers". These managers are not responsible for the functional organizations as a whole, but for their team of individuals from each organization. The mission of each team is product family focused and not functionally focused. The culture within these teams is already strongly attuned

to getting the job of building quality product on time. An effort of this nature fits nicely with that mission.

In order to make all of this shared effort and accountability happen, upper management must provide middle and lower level management (functional and product family managers alike) with a clear and concise vision of what is being implemented and why. They must "champion" the idea to the functional ranks or it will be labeled as aforementioned, and it will likely fail. This theme is prevalent in the organizational change literature and noted by Schein.²³

7.2 Recommendations for Further Improvement

The other major area needing improvement is the management of material. There are two issues here: vendor management and stock level management. Strategies for vendor management and stock levels should reflect the goals of the organization. The goal in the materials organization should therefore be to provide production with the required material 100% of the time.

Although there may be a temporary rise in inventory costs, the stocking levels of all items should be adjusted to accommodate all types of uncertainty in the material supply process for each item. Given the level of late orders due to missing material, it is clear that these levels are too low.

As a concurrent activity, the management of vendors needs to be improved. With vendor on time delivery rates in the mid 80% region, it is clear that vendors do not understand the effect their late deliveries have on DEC's performance as a business. DEC can never expect to have an efficient on time manufacturing operation until its vendors deliver material in a timely manner. This message should be communicated to the vendors in two ways. First, existing communication lines should be used to clearly define present levels of

²³ Edgar H. Schein. Organizational Culture and Leadership. (San Francisco: Jossey-Bass Publishers, 1992). p. 209.

performance (for the particular vendor) and an expected future performance goal. Second, future vendor contracts could be structured to require certain levels of delivery performance.

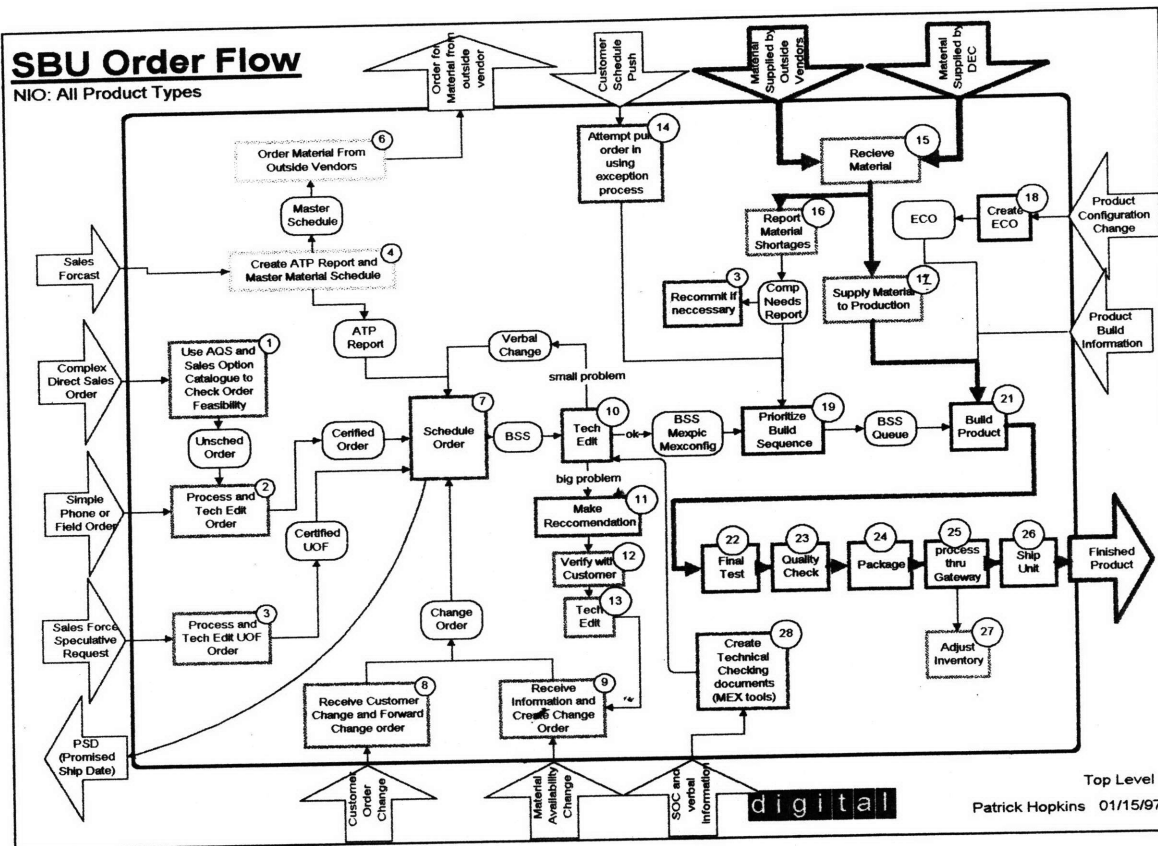
Appendices

Appendix One: Activity Based Flow Charts

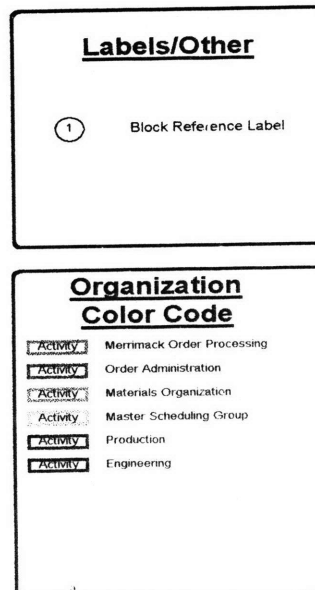
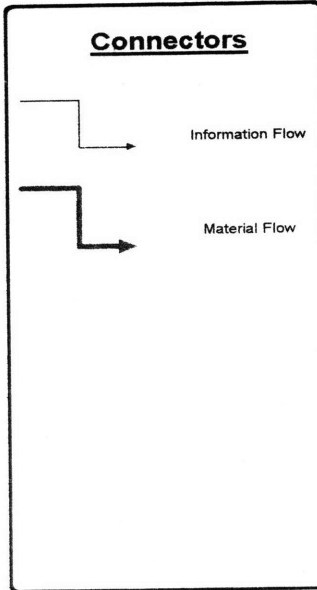
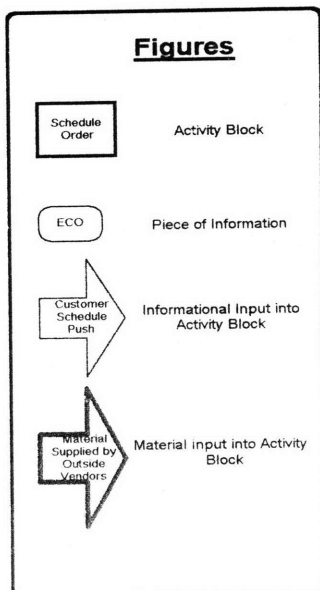
For Desktop Business

The first significant activity conducted was to document the flow of an order through the Salem facility. Included in this appendix are those flow charts. The first page includes the "top level" view of the process and the key of figures. The remaining pages are additional detail for many of the activities on the top level. They are numbered accordingly.

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Key of Figures and Colors



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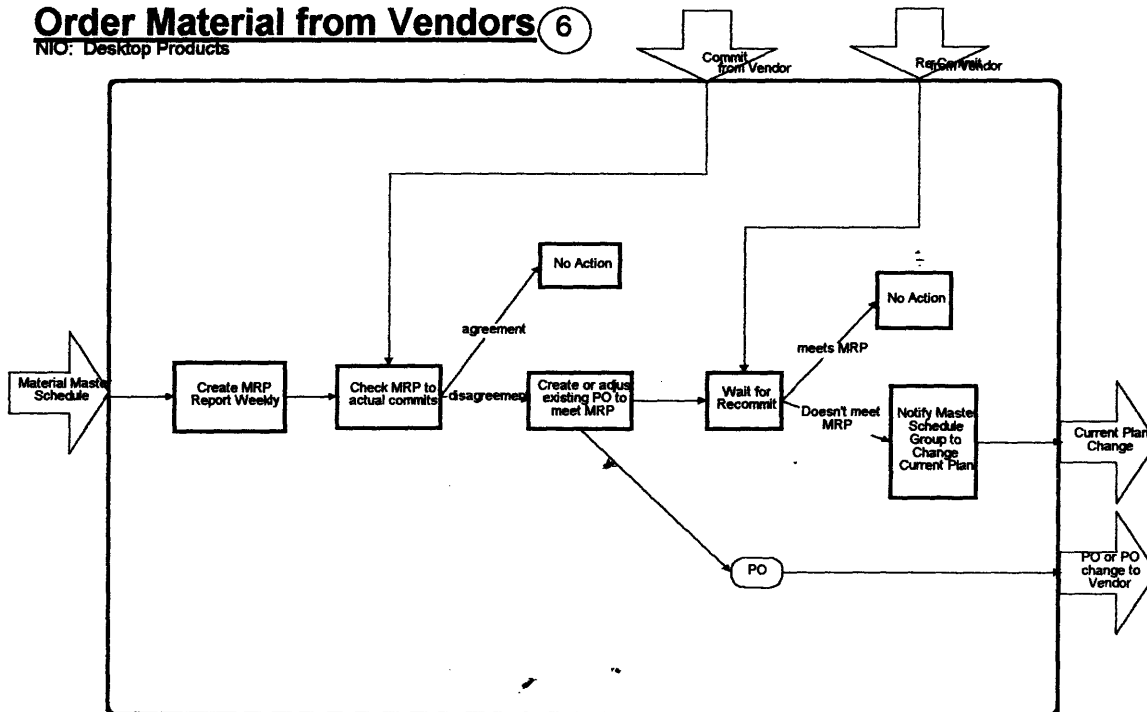
Key
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Improving Order Fulfillment Predictability

Order Material from Vendors ⑥

NIO: Desktop Products

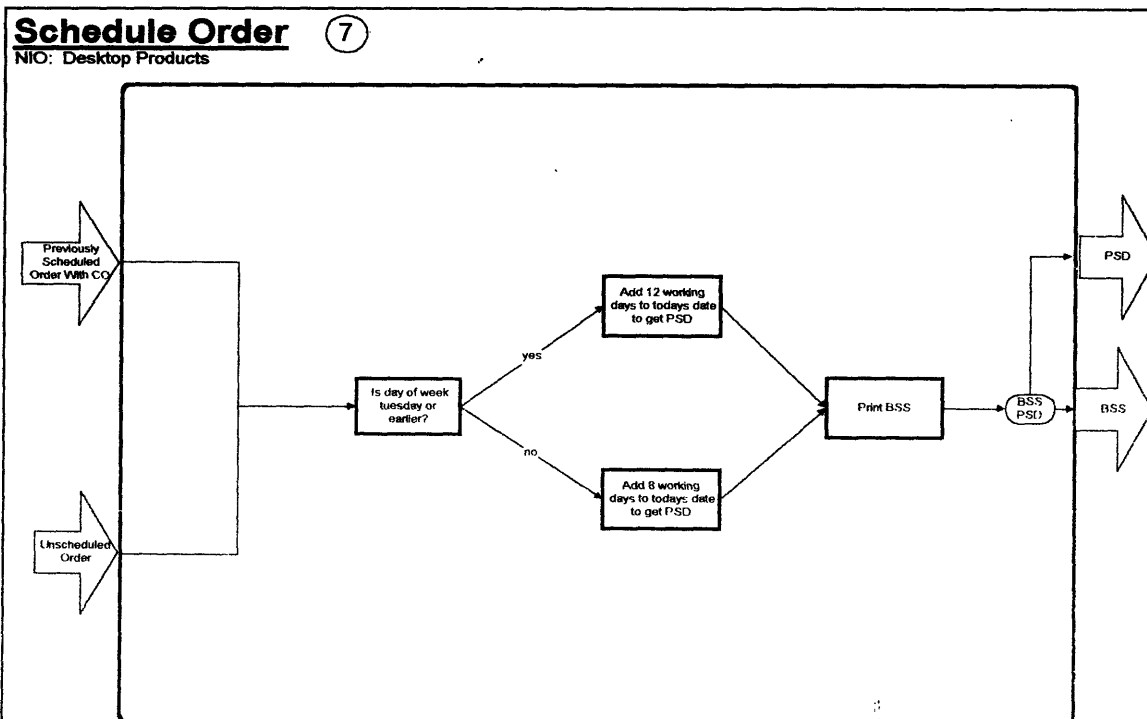


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Order Material From Vendors
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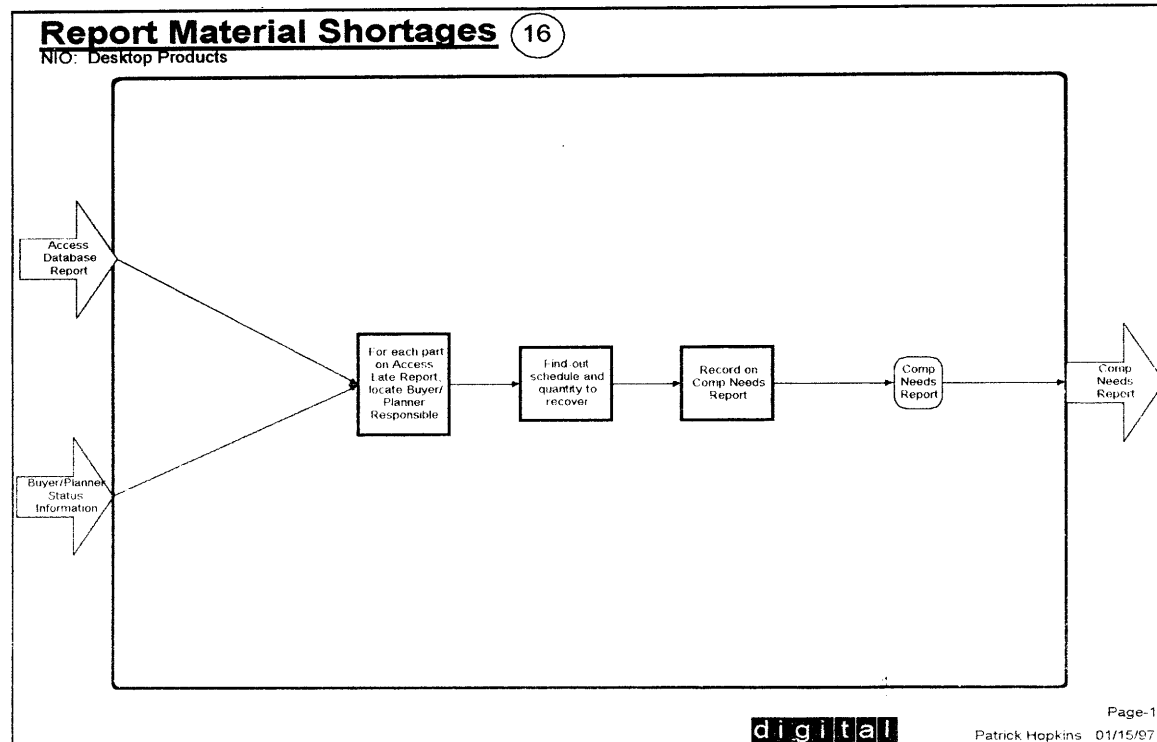
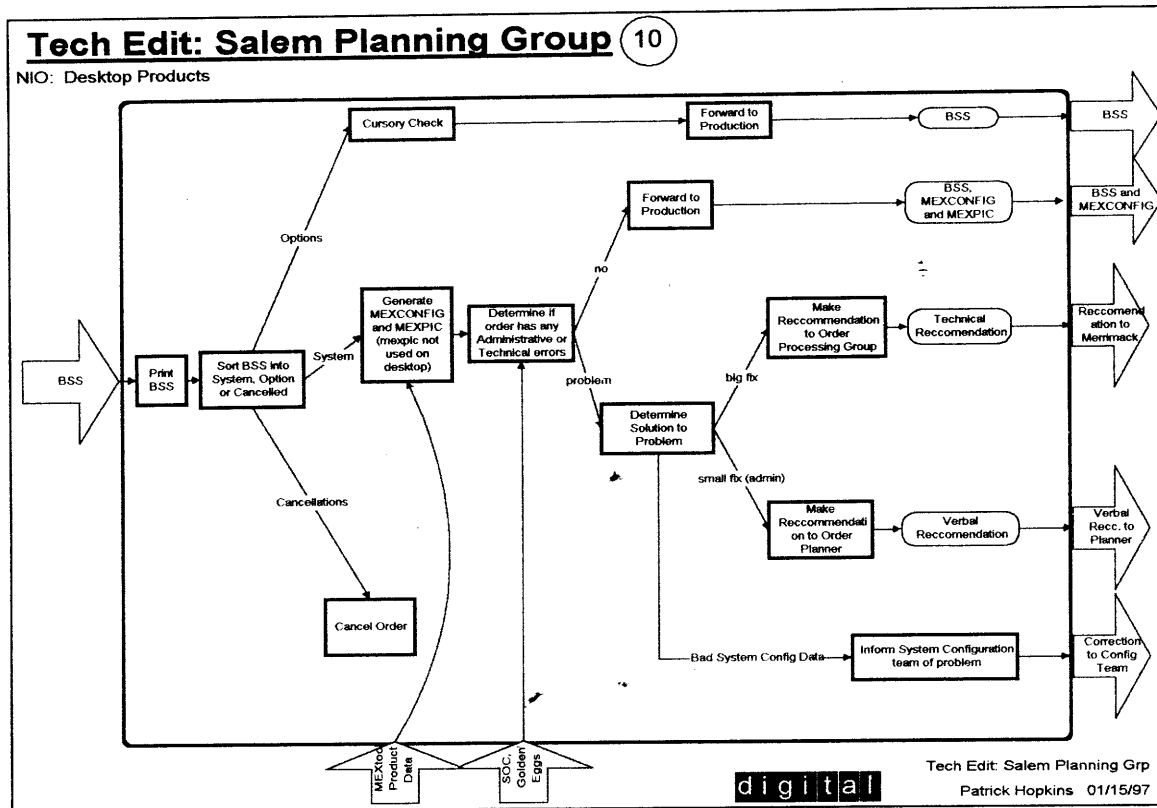
Schedule Order ⑦

NIO: Desktop Products



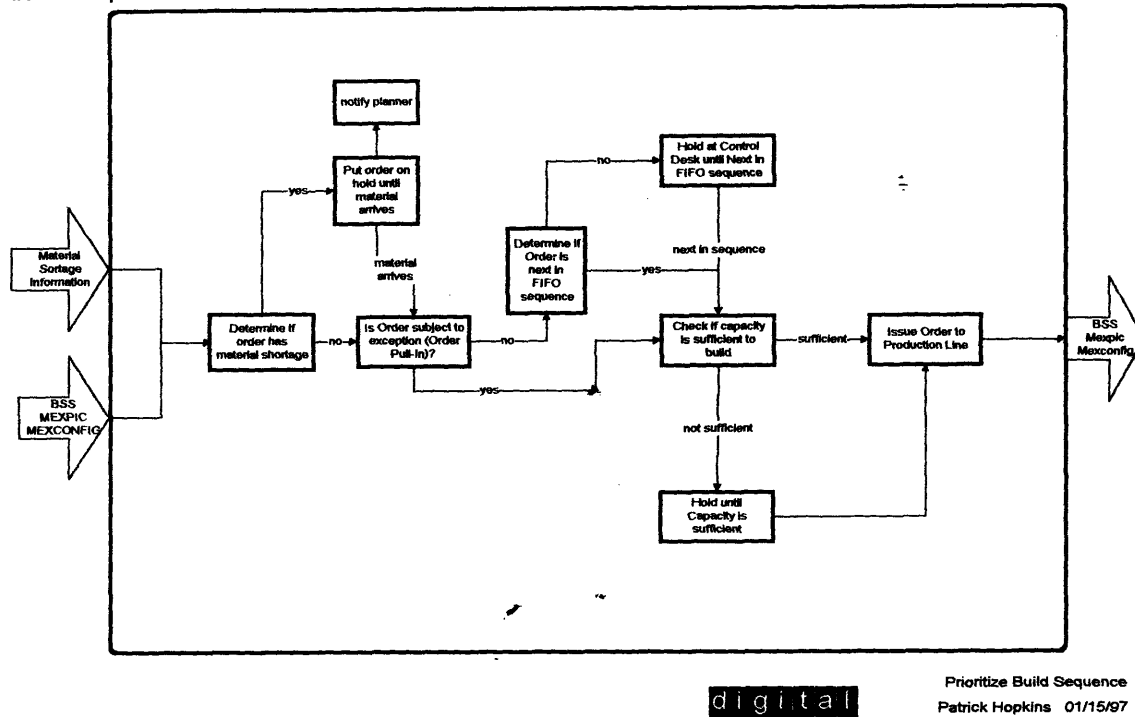
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Prioritize Build Sequence 19

NIO: Desktop Products

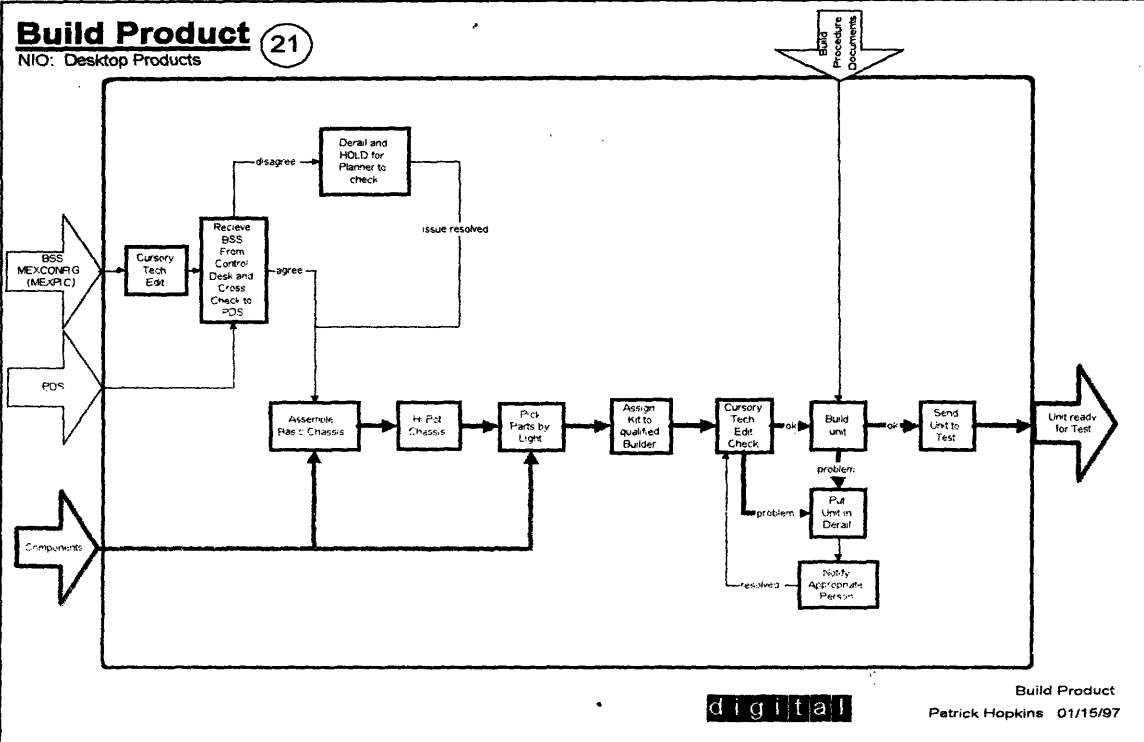


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Prioritize Build Sequence
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Build Product 21

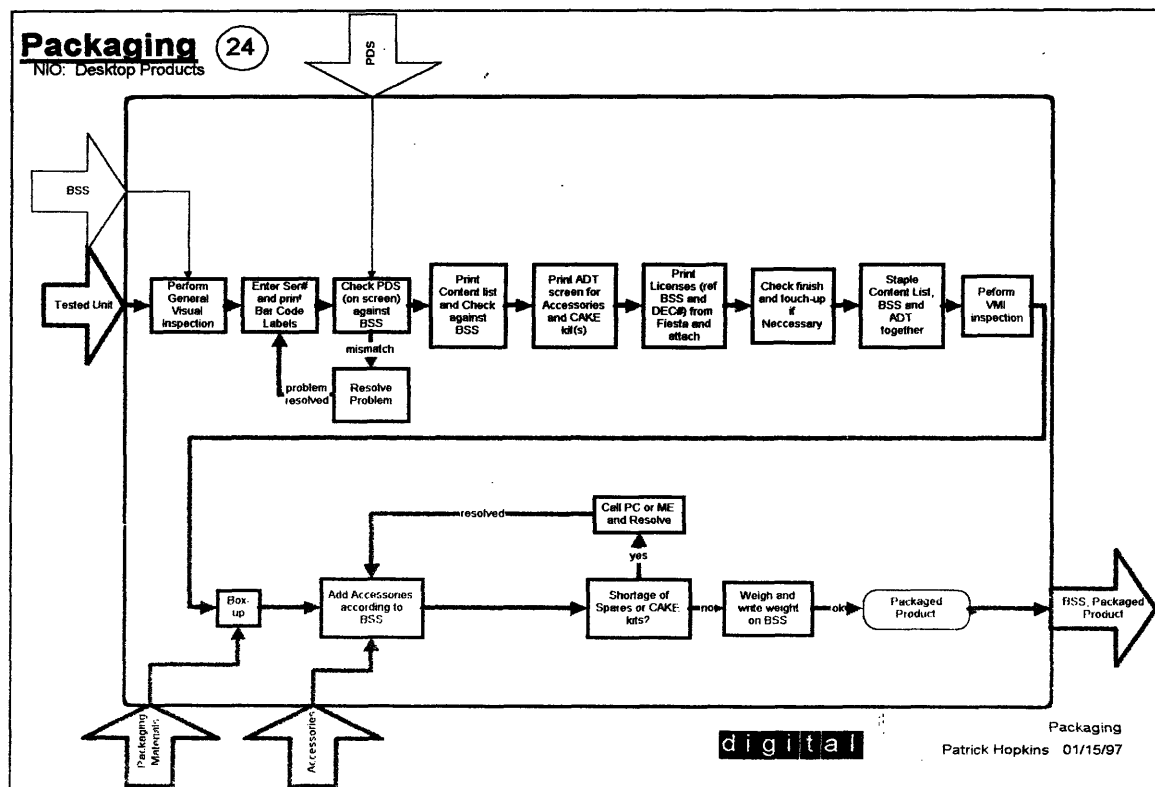
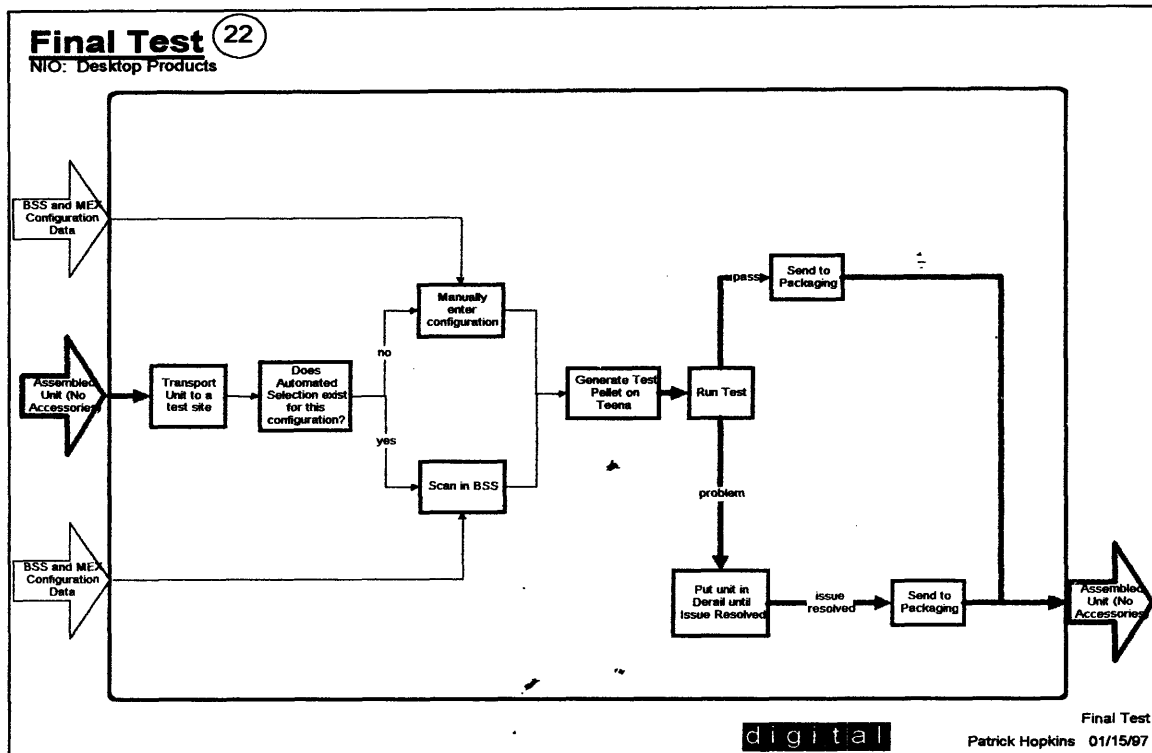
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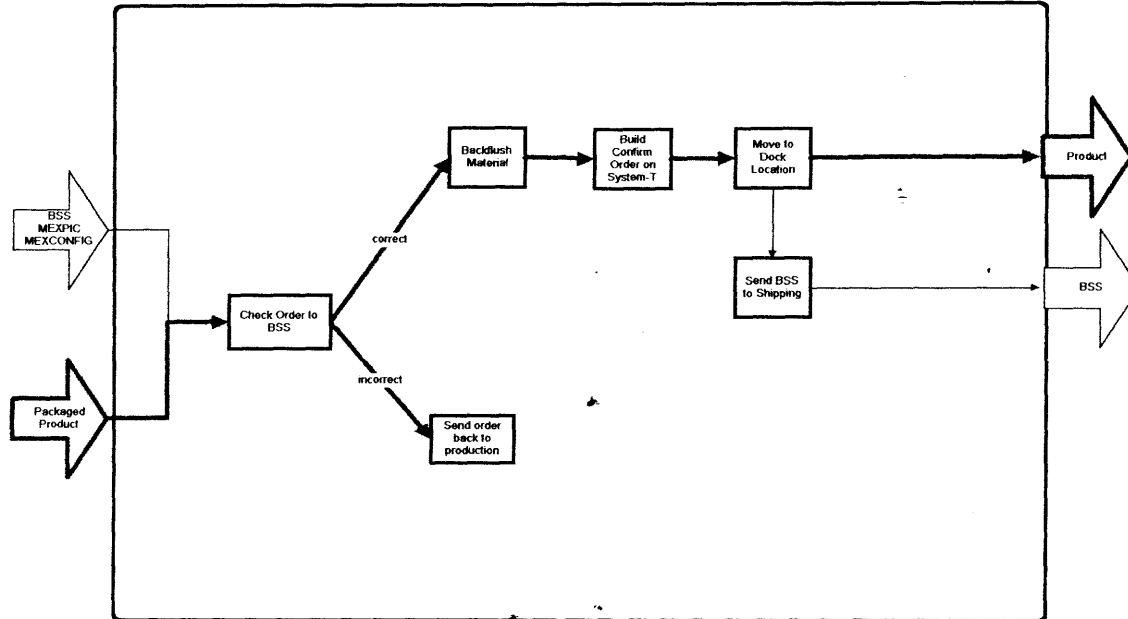
Improving Order Fulfillment Predictability



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Gateway Processing (25)

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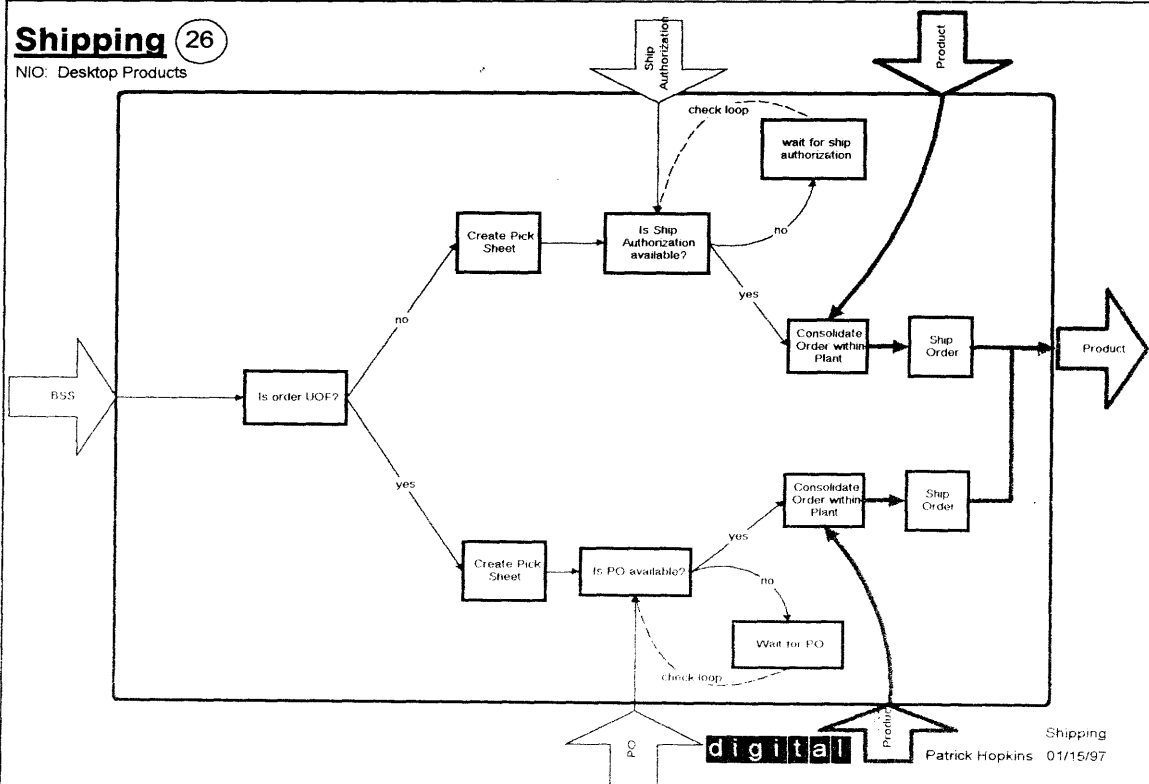


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Gateway Processing
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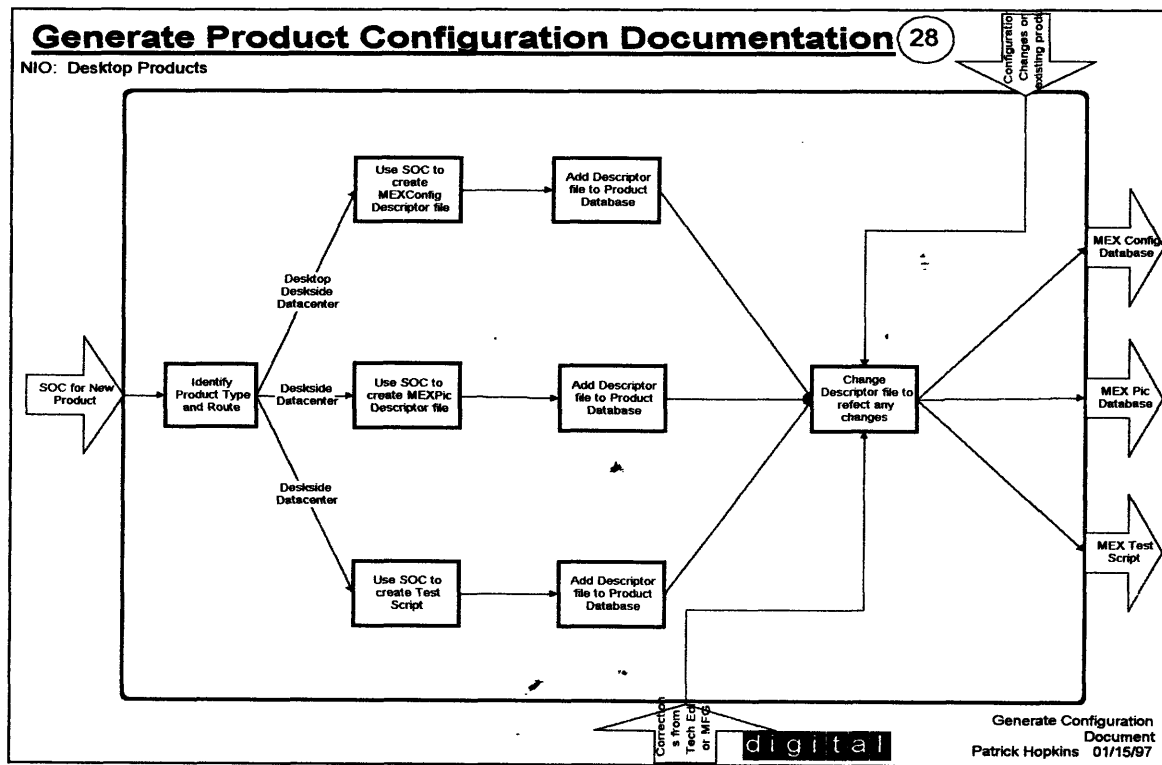
Shipping (26)

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Shipping
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