DESIGN FOR MATERIAL LOGISTICS

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(continued on page 76)

A key business strategy for Definity® system private-branch exchanges (PBXs) is offering the customer the ability to customize a system to match his or her needs. This is possible because the Definity PBX architecture allows design of an almost limitless number of customer end item configurations from a limited set of buildable options (e.g., circuit packs). Though this customization is an attractive selling point, it complicates PBX manufacturing. It can also be costly to the manufacturing organization if done without prior installation of capabilities to deal with a high level of product optionality. To do this in AT&T required the support of the company's PBX design community. In particular, the traditional single-design documentation was complex and cumbersome, and had to be broken up into several simpler documents that reflect the product's buildable options and physical hierarchies (e.g., cabinets, carriers, circuit packs). This paper will review the change and explain its implications and effect on high-option manufacturing.

Introduction

The cost of material, and the cost of managing the planning for and movement of that material, can collectively account for 85 to 90 percent of the total cost of manufacturing electronic products. The inventory carrying costs associated with this material also can be substantial. Thus, the ability to compete successfully in manufacturing is dictated largely by the ability to incorporate into the design the proper set of components, and to balance, at the lowest cost, the supply and demand for material. For simple products, the management of material is straightforward. For complex, highly optioned products such as PBXs, effective material management is a major challenge, but can mean the difference between manufacturing success and failure.

Panel 1. Terms and Acronyms in This Paper

BOM	bill of materials
carrier	a specific type of unit designed solely to hold circuit packs
comcode	a 9-digit number assigned to a component
end item	a product sold as a completed item or repair part, or as any item subject to customer orders or sales forecasts
feature table	describes different options and the corresponding stock lists that provide those options
J drawing	an equipment drawing that includes wiring
JIT	just in time
MPS	master production schedule
MRP	material requirements planning
PBOM	planning bill of materials
PBX	private-branch exchange
stock list	associates lists of the components (i.e., framework, apparatus, and subassemblies) needed to manufacture equipment
TQC	total quality control
unit	used to refer to all types of units, including carriers
unit reference table	identifies the drawing and main list of the units that can mount in the cabinet

AT&T's Denver Works understood this challenge. Over a span of three years, by aggressively implementing fundamental material requirements planning (MRP) principles and other manufacturing initiatives,[1] the factory's management was able to slash inventories by 90 percent and reduce manufacturing intervals by 75 percent. Because of these improvements, we believe the Denver Works is now among the preeminent factories in the world involved in manufacturing highly optioned electronic systems whose order flows tend to vary widely. The manufacturing initiatives that allowed it to achieve this position would not have been possible without first implementing a simple but essential change in its design documentation structure.

The Denver Works manufactures the Definity communications system line of PBXs and other products. Its objective is to manufacture and ship complex customer-configured systems at the lowest cost and shortest interval. To achieve this objective required that the planning and management of *all* materials and subassemblies be tightly synchronized and controlled. Applying MRP to simple products is straightforward. Simplifying the design drawings enabled the factory to extend application of MRP to complex, highly optioned products such as the Definity PBX.

Complete implementation of MRP stabilized and brought under control the flow of material, facilitating just-in-time and total quality control (JIT/TQC) techniques that further reduced manufacturing intervals and minimized the expense of maintaining costly inventories. The documentation changes also reduced the customer order delivery interval by greatly simplifying and contributing to the mechanization of order processing at the Denver Works.

This paper will concentrate on the first, perhaps most critical step in the manufacturing improvement initiatives—simplifying design drawings. An account of other aspects of these manufacturing initiatives and their results will appear in a future issue of the *AT&T Technical Journal*.

Design for Material Logistics

Various aspects of designing products for material logistics have been discussed by others.[2,3] From a material logistics perspective—i.e., from the point of view of how material is moved and managed—an ideal product should be designed with the following considerations:

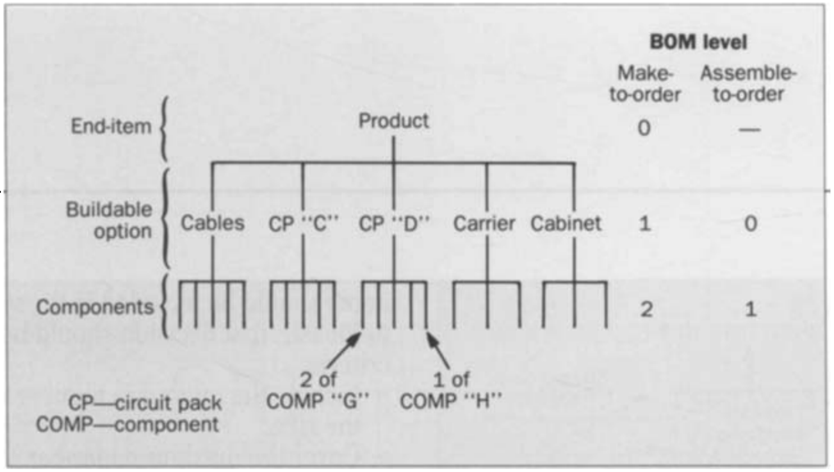


Figure 1. Simple example of a traditional bill of material for an electronic equipment product.

- A minimum number of possible parts
- Standard or "preferred" parts
- A modular and reusable physical architecture
- A limited set of end item configurations (an *end item* is a product sold as a completed item or repair part, or as any item subject to a customer order or sales forecast)
- A modular product and bill-of-materials (BOM) structure.

With respect to the first three considerations, AT&T's PBX designs were already well positioned and no redesigns were needed. With respect to the fourth consideration, although there is a cost benefit to offering limited product configurations, the business strategy dictated that the products be customized to meet customer needs. Thus, offering only a limited set of configurations was not an option. The last consideration, a modular product and BOM structure, was the remaining and perhaps most critical issue.

Material Requirements Planning

In the past, the Denver Works planned and released material and shop orders based on forecasts. Customer orders were then assembled to order from a pool of work in process and finished subassemblies. But because the forecasts frequently did not match orders, the "right" material was not always available to build the product.

To meet production schedules, the factory tended to order and build excess inventory "just in case" it was needed. Informal systems were developed to expedite material that was not in inventory. Expediting creates considerable churn in the process, results in the breakdown of formal processes, and makes it impossible to achieve disciplined manufacturing techniques such as JIT. To remain competitive, it was crucial that the Denver Works introduce greater discipline into its manufacturing operations and improve its synchronization of material demand with material supply.

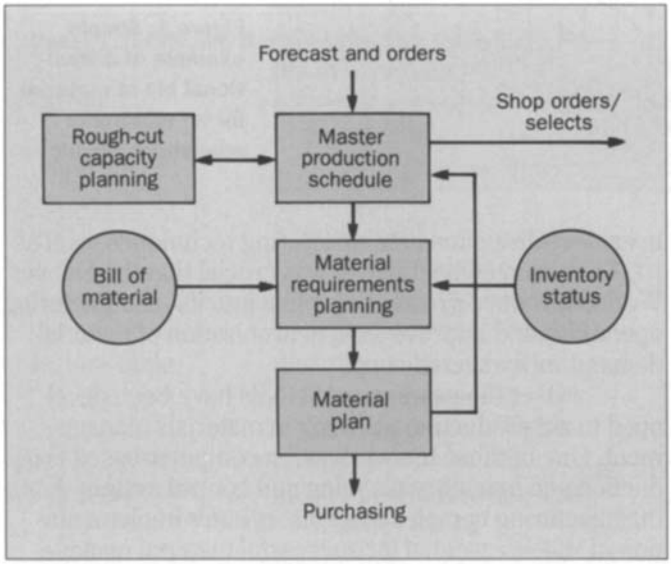
Over the years, several tools have been developed to aid production planning in materials management. One of those tools is MRP,[4] a computer-based production and inventory planning and control system. For manufacturing complex systems, *effective* implementation of MRP is essential for successful material management and standardized material flow. Deploying an MRP system does the following:

- Gives the material management function discipline and a common language.
- Provides a tool to more accurately plan and control material.
- Allows the factory to accept and plan for additional orders with minimal disruption.

A fundamental goal of an MRP system is to balance component and subassembly supplies to time phased product demands. Therefore, MRP is ideally suited to managing intermittent customer demands. It does not solve the forecast problem but does allow better management in a highly volatile environment.

Essential to the MRP system is an accurate and current BOM that describes not only what material is required (e.g., stock list) but also how the product is put together. The BOM needs to be defined to support not only design and engineering but also manufacturing, production planning, and order processing. Figure 1 shows a simple example of a traditional BOM for an electronic equipment product.

Master Production Scheduling. Figure 2 presents a



64

Figure 2. A schematic of a basic MRP system. MRP is driven by the master production schedule (MPS), an expected-build schedule stating in detail how many end items are to be produced, and when.

schematic of a basic MRP system. The MRP is driven by the master production schedule (MPS), an expected-build schedule stating in detail how many items are to be produced, and when. The MPS focuses on the products to be manufactured and, through the detailed MRP planning system, determines the resources required and their timing. The fundamental purposes of the MPS are to:

- Initiate procuring the resources necessary to implement the plan.
- Serve as a common plan to coordinate marketing, sales, engineering, manufacturing, and finance.
- Serve as a tool to reconcile marketing and sales requirements with manufacturing capabilities.

Figure 3 shows an example MPS grid and its MRP logic based on the BOM shown in Figure 1.

BOM Structuring for the MPS. The decision on what items should be included in the MPS is critical. According to Plossl,[5] that decision should be based on the following criteria:

- Include the minimum number of possible items in the MPS.
- Cover the maximum number of components in the MRP program driven by the MPS.
- Generate the maximum possible amount of information about loads on manufacturing facilities.

Within AT&T, products generally fall into one of two categories:

- *Make-for-Stock*. Make-for-stock products generally are high volume products with few, if any, configurations. They are manufactured without customer orders, and are placed in storerooms until orders are received. Examples include telephone sets and personal computers. For these types of products, master scheduling at the end item level is ideal. Forecasts are developed for the end items and, as orders are received, the forecasts are consumed by these orders. (*Consuming* a forecast means that the forecast—an estimate—is either partially, fully, or over-realized by orders.)
- *Made-to-Order*. These are products that have almost limitless configurations, but are made up of a fixed set of components or sub-assemblies (e.g., circuit packs). An example is the Definity PBX line.

For made-to-order products, master scheduling at the end item level is unacceptable because the almost limitless number of end items are impossible to forecast accurately and schedule with any hope of validity. Instead, the recommendation[6] for products of the complexity of a PBX is to establish the MPS at the buildable option or module level. (A *buildable option* or *module* is an intermediate product, subassembly, or group of parts that makes up an *item*.) The methodology implemented at the Denver Works is to schedule the buildable options. A buildable option has no variation within it, but is an option in itself. Examples of buildable options include circuit packs and specific cabinet configurations without carriers or circuit packs. (Note that terminology differs among AT&T

MPS Grid

End item "A"	1	2	3	4	5	6	7	8	9	10	11	12
	Period (weeks)											
Forecast									15	15	20	20
MPS									15	15	20	20
Projected available									0	0	0	0
On-hand									0	0	0	0

Circuit Pack "D"	1	2	3	4	5	6	7	8	9	10	11	12
Requirements							15	15	20	20		
Scheduled/receipts												
On-hand							0	0	0	0		
Planned order release				15	15	20	20					

Component "G"	1	2	3	4	5	6	7	8	9	10	11	12
Requirements				30	30	40	40					
Scheduled/Receipts												
On-hand 10				0	0	0	0					
Planned order release	20	30	40	40								

Component "H"	1	2	3	4	5	6	7	8	9	10	11	12
Requirements				15	15	20	20					
Scheduled/Receipts												
On-hand 15				0	0	0	0					
Planned order release	0	15	20	20								

Figure 3. An example MPS grid and its MRP logic based on the bill of material shown in Figure 1.

business units. *Cabinet* is comparable to *frame* and *bay*. *Carrier* is comparable to *unit* and *shelf*. For specific examples, we will use the term *carrier*, which is a specific type of unit designed solely to hold circuit packs. We will use *unit* to refer to all types of units including carriers.)

Because the buildable options or modules are simply manufacturable subassemblies, all that is required to support an MPS strategy for made-to-order products is to treat the sub–assemblies as products. Therefore, the buildable options become the highest level of the BOM for purposes of the MPS. This has the effect of designating them level 0 instead of level 1 in the bill-of-material structure. This is also shown in Figure 1.

For made-to-order products, forecasts are developed for typical products. These include *planning* bills of materials (PBOM) for an end item where component (in this example, buildable option) quantities are based on average usage over some time period. For the Denver Works, the averages are based on a forward look at customer order configurations. The typical product forecast is then exploded, using the PBOM, into buildable

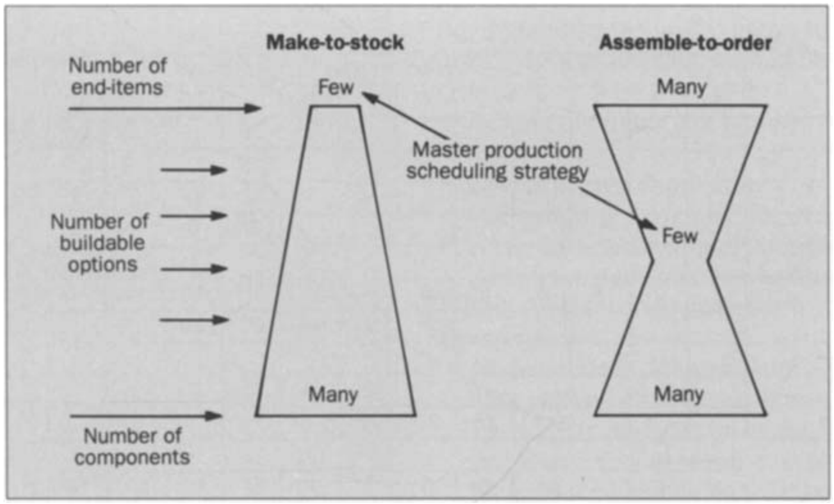


Figure 4. Master production scheduling strategy for various types of products, illustrating the differences between the MPS strategy for make-for-stock and assemble-to-order products.

options managed by the master production schedule. As orders are received from the customer, the actual quantities of buildable options exploded from the orders are used to consume the forecast in the MPS.

Another example of a made-to-order product is an automobile. A model may have about 30 options from which a customer can select. Overall, there may be over a million combinations. An automobile manufacturer, however, will not and cannot schedule each combination in the MPS. The manufacturer will instead schedule the individual options such as air conditioning and automatic transmission.

Figure 4 illustrates the differences between the master production scheduling strategy for a make-for-stock product and a made-to-order product.

Design Documentation

To assist in implementing the modular product and BOM structure—and thus the desired MPS strategy—changes had to be made to the traditional design documentation. This section will describe the traditional documentation and the changes that were required.

In AT&T, an *equipment drawing* is one that is used to document circuitry, equipment, BOM, parts, or stored program software. It provides manufacturing information to the shop, engineering information to both AT&T and customer engineering organizations, installation information to installation forces, or maintenance information to service forces. However, the traditional drawings do not necessarily support production planning, order processing and other functional organizations.

Three types of equipment drawings predominate in AT&T: *J*, *ED*, and *H* drawings. In general, equipment that includes wiring is documented by J drawings. Equipment without wiring (e.g., framework, cable assemblies) is documented by ED and H drawings. Though we focus on J drawings in this article, the same ideas and concepts apply equally to the other types of drawings.

J Drawings. A drawing consists of text (tables and notes) and graphics that not only specify the contents of, and the assembly and wiring requirements for, the equipment, but also define the options available. A sample drawing identifier is J12345A-1.

The primary elements of the drawings treated here are the feature table (Table A) and stock list. The other drawing elements (e.g., engineering, manufacturing and installation notes, issue notes, specific and miscellaneous table information, graphic sketches, and details of parts) are extraneous to this discussion. For illustrative purposes, a simple, hypothetical set of equipment drawings demonstrating the elements of interest are shown in Appendices A and B.

- A *feature table* provides descriptions of different options and the corresponding lists that provide those options. Lists are alphanumeric identifiers assigned by designers to subdivide the components of the equipment and to designate optional features.
- A *stock list* defines the components (i.e., framework, apparatus and subassemblies) required to manufacture the equipment. The stock list is the basis for the BOM used in manufacturing.
- A *main* list (List 1 in Appendices A and B) identifies the common or basic equipment. *Supplementary* lists (all other lists in Appendices A and B) identify equipment or apparatus required to provide optional features on the basic unit.

Supplementary lists frequently do not identify buildable items. They provide buildable options by making additions or deletions to the stock list entries for another list. For example, see the stock list entry for List 6 in Appendix A. The set of lists consisting of the main list and all supplementary lists selected to provide specific options, determines one possible end item that can be defined by a particular drawing.

Traditional Drawing Structure. The equipment described by J drawings is configured hierarchically. That is, a cabinet is configured by mounting one or more carriers in it. Carriers are configured by mounting one or more circuit packs in them. Therefore, the traditional drawing structure has evolved to describe this hierarchy by duplicating the lists (both main and supplementary) from the carrier drawings on the cabinet drawings. Under this drawing structure, the six feature descriptions shown in the carrier drawing (Lists 1 to 6 in Appendix B) are duplicated in the cabinet drawing (Lists 7 to 12 in Appendix A). The carrier drawing is also referenced in the stock list of the cabinet drawing. (Note that though the cabinet-carrier(s)-circuit pack hierarchy is the most common, it is also possible to have a cabinet–unit(s)–unit hierarchy where one unit can be mounted in another unit. The ideas and concepts described in this article apply equally to this more complicated hierarchy.)

Compared to the hypothetical examples discussed, equipment drawings are generally more complex because they have more lists. And they have more lists because a cabinet will generally contain several types and quantities of subassemblies. For example, most cabinets will require a power unit, a fuse and alarm unit, and various carriers that provide the specific functionality for the cabinet. It is common for a cabinet drawing to require over 100 lists to specify these sub-assemblies and their options.

A major consequence of this hierarchy of drawings and the large number of interdependent lists are the many combinations and, thus, end items available. Planning the material requirements for the almost limitless end items is impossible. Simplifying the J drawings is required to minimize the dependencies and lists, thereby making visible the minimum set of options for the master production schedule.

New Drawing Structure. A simpler structure has evolved for the equipment drawings used for Denver's products. It allows master scheduling at the more manageable buildable option level but, at the same time, does not negatively affect other functional areas in the product realization process. This simpler structure does not affect the functionality offered to customers. Two fundamental changes were made in the design documentation to simplify the drawings:

- Interdependence between drawings was eliminated.
- Circuit pack lists were removed from carrier drawings.

Drawing Interdependence. This change removed subassemblies—in this case, carriers—from the stock list and feature table of cabinet drawings. This eliminated interdependence between unit and cabinet drawings at the feature table and stock list level. These changes are illustrated in Appendix C. (Note that technical interdependencies remain and are still documented in other notes and tables on drawings. However, these interdependencies are no longer reflected in the drawing structure.)

In making this change, the need remained for users (e.g., customers, engineers, material planners) to be able to determine what units can be mounted in a cabinet. The new method for providing this information is to add a unit reference table (see Appendix C) to the cabinet drawing, and to add an engineering note (not shown) that directs the user to this table. This table identifies mandatory and optional units, directing the user to the unit drawing that contains all required engineering and manufacturing information. Thus, user needs were met without redundant maintenance of this information.

Circuit Packs. Going one step further, design engineers removed circuit packs from the feature table and stock list of carrier drawings (see Appendix D). This reduced the number of lists and associated stock list entries on the carrier drawing, and made the circuit packs more visible (and more manageable) in the customer order. All information about circuit packs that was previously contained in the stock list and feature table was placed in a circuit pack table augmented by specific engineering notes (not shown) to facilitate ordering and engineering. Thus, there was no loss of information on the drawing.

Other Changes. Though the two changes described above were the most significant in terms of traditional design documentation, other changes were made case by case within the traditional documentation structure. One example of this type of change involves incorporating a frequently ordered supplementary list into the main list if this is more cost-effective than offering it separately. The critical factor for implementing these as well as the other changes was—and is—an ongoing dialog among the material planners and manufacturing engineers in the factory and the product designers.

Other Alternatives. Besides simplification of the drawing structure, other alternatives considered included:
- *Include all end item configurations in the MPS.* As noted, this alternative was not feasible because of the almost limitless end items that would have to be scheduled.
- *Include a partial and select set of typical end item configurations in the MPS, and, as orders are received, add or delete end items in the MPS.* This alternative was also not acceptable since it is unlikely that material will be present in time to manufacture the non-typical order where "adds" are required.
- *Implement the MPS at the option level with the original drawing structure.* Because of the redundant representation of product identifiers, this would have introduced enormous complexity into the management of BOMs, since each option could have multiple valid representations. The magnitude and complexity of the on-going maintenance effort required of material planners, as well as the time and cost required to implement software changes to support this complexity, made this an unacceptable alternative.
- *Include all individual lists in the MPS.* As mentioned earlier, lists are frequently not buildable items. Master production scheduling is a *production* planning tool, not a *component* planning tool. Using the MPS merely to plan components is not master production scheduling, and minimizes its use by not only manufacturing but also other functional organizations.
- *Do nothing.* This implies staying with the previous process of planning and building assemblies based on a forecast, and assembling and expediting based on orders.

Overall, none of these alternatives were viewed as feasible or desirable for a competitive manufacturing environment.

Effect of Changes

Simplifying the drawing structure had several major benefits in terms of material logistics planning, management information systems, and creating and maintaining drawings, and order processing.

Material Logistics Planning. As described earlier, an objective in material planning for a made-to-order product is to be able to schedule the MPS at the buildable option or subassembly level. For this to be efficient, the task is to define a BOM structure that results in the minimum buildable options.

By way of illustration, consider the hypothetical carrier shown in Appendix B. The various ways its four circuit packs can be selected to fill the sixteen available positions (shown as positions 0-3, 5-8, 13-16, 18-21 in the stock list) exceeds a billion combinations, each in theory a buildable configuration. (For each of the sixteen positions, there are five possibilities: one of the four circuit packs or no pack. Thus, the total possible combinations are 5^{16} or 152,587,890,625.) Thus, it is clearly impossible to select carriers equipped with circuit packs as the intermediate product to schedule.

With the removal of circuit packs from the feature table and stock list, (see Appendix D), the main list for the carrier and its one supplementary list combine in two different (and mutually exclusive) ways to produce the buildable carrier configurations. Thus, if we include the four circuit packs—also buildable options—only six buildable options need to be managed for the factory to be able to make to order all possible combinations of this carrier instead of an almost limitless number.

Management Information Systems. As we noted, MRP is a computer-based, production and inventory planning and control system. In the traditional drawing structure, available systems were not capable of *effectively* supporting highly optioned products. Simplifying the drawing structure removed this hurdle and allowed complete implementation of an MRP system.

Also, the simplified drawing structure facilitated the local development of a computerized, rule-based engineering system that supports overnight engineering of *all* system orders received at the factory. Rapid availability of the detailed option requirements for an order works hand in hand with the MPS and MRP systems to support effective material management.

Creation and Maintenance of Drawings. The hierarchical standards described required duplicating most of the information from unit drawings (feature table descriptions, stock list elements and pertinent notes and other data) on cabinet drawings. If the unit itself contained subassemblies, then another level of duplication was required. By eliminating this duplication, these simplifications reduced the effort of creating new drawings.

In the life cycle of any product, design and manufacturing changes normally add new features or alter existing features. This results in changes to the feature table and stock list. Under the hierarchical system, changes to units also affected cabinet drawings. By reducing drawing change activity, this new drawing structure reduced the effort of maintaining equipment drawings. [Since the unit reference table (Appendix C) identifies the drawing and main list of the units that can mount in the cabinet, changes propagate when the unit drawing or its main list change. However, this does not affect the stock list or feature table of the cabinet drawing.]

Order Processing. Another advantage of the new drawing structure was eliminating duplicate orderable product identifiers. For example, before these changes, a component such as a circuit pack was identified by a *comcode*, i.e., a 9-digit number assigned to it (e.g., 103278792 for an SN240 circuit pack). The same component ordered by a list on a carrier drawing was also identified by that drawing and list combination (e.g., see stock list entry for J12345AA-1 L-6 in Appendix B). This carrier option ordered by a list on a cabinet drawing was also identified by the cabinet drawing and list combination (e.g., stock list entry for J12345A-1 L-12 in Appendix A). Thus, this single component had three separate identifiers (103278792, J12345AA-1 L-6, and J12345A-1 L-12), all of which provided the same SN240 circuit pack and could appear in the customer order stream. If this component was also used in other carriers, that were used in other cabinets, the multiplicity of product identifiers expanded accordingly. With these changes, the single identifier for the component is the comcode.

Summary

The implications of design on material logistics in a factory have been discussed. In particular, simplifying equipment drawings to reflect the minimum buildable options is an example of designing for material logistics. The effects of this change are that:

- Fully implementing MRP is now feasible because the design documentation makes it possible to identify and material-plan the minimum number of buildable options. The Denver Works is now:
  1. Better able to balance *all* material supply and demand because there is now complete visibility between what has been forecast and what has been ordered.
  2. Better able to commit to and manufacture on time customer orders since the required material is almost always present when needed.
- All equipment drawings are significantly simplified, with a corresponding reduction in creation and maintenance efforts.
- Duplicate product identifiers are eliminated to tightly link customer orders with the factory's planning and execution systems.
- The engineering change process is less error prone and more responsive because the dependencies between drawings and changes is greatly reduced.
- Computerized engineering of all product and order processing is greatly simplified.

As was previously noted, the drawing documentation change and eventual full implementation of MRP also had additional benefits because it made it much easier to implement JIT/TQC programs on the shop floor. The MRP implementation brought stability to the material logistics operation and greatly reduced the material shortages that would have undermined the implementation of JIT/TQC. The drawing changes also allowed the factory to move toward a single level BOM. This eliminated the many MRP control points that would have artificially inflated the manufacturing intervals and impeded material flow.

The net benefits of these improvements and process simplifications are that the Denver Works, after a few years, was able to reduce inventories by 90 percent and reduce order processing and system manufacturing intervals by 75 percent. There was also a significant cost avoidance and lessening of white collar support that would have been needed to support complex order processing and material expediting operations.

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Appendix A. Hypothetical cabinet drawing J12345A-1

TABLE A - FEATURES							
			EQUIPMENT OR CIRCUIT DATA				
EQUIPMENT	LIST	QTY	EQUIPMENT OR CIRCUIT	LIST GROUP OR FIG	WRG	APP	NOTE
FRAMEWORK, ASSEMBLY, WIRING AND EQUIPMENT FOR ONE BASIC CABINET	1	1 1	SD-1E550-01 ED-1E456-70	 GR-4			60
APPARATUS REQUIRED IN ADDITION TO LIST 1 TO PROVIDE SEPARATE THERMAL SENSOR UNIT (SEE NOTE 55).	2	1	ED-1E430-70	GR-1			
INTRA CABINET CABLE ASSEMBLIES REQUIRED IN ADDITION TO LIST 1 FOR FIRST PORT CARRIER.	3						
INTRA CABINET CABLE ASSEMBLIES REQUIRED IN ADDITION TO LIST 1 FOR SECOND OR THIRD PORT CARRIER (MAX - 2 L-4).	4						
APPARATUS REQUIRED IN ADDITION TO LIST 1 TO PROVIDE 8 HOURS OF BATTERY RESERVE FOR T.O.D. CLOCK.	5						
APPARATUS AND WIRING REQUIRED IN ADDITION TO LIST 1 WHEN EXTENDED POWER RESERVE IS REQUIRED.	6	1	SD-1E552-01				62
EQUIPMENT REQUIRED IN ADDITION TO LIST 1 TO PROVIDE ONE PORT CARRIER.	7	1	J12345AA-1	L-1			
APPARATUS REQUIRED IN ADDITION TO LIST 7 WHEN CABLE ROUTING IS THROUGH THE OVERHEAD DUCT.	8	1	J12345AA-1	L-2			
APPARATUS REQUIRED IN ADDITION TO LIST 7 WHEN CARRIER IS TO BE EQUIPPED WITH CONTACT INTERFACE (SN241).	9	1	J12345AA-1	L-3			
APPARATUS REQUIRED IN ADDITION TO LIST 7 WHEN CARRIER IS TO BE EQUIPPED WITH AUXILIARY TRUNK (SN231).	10	1	J12345AA-1	L-4			
APPARATUS REQUIRED IN ADDITION TO LIST 7 WHEN CARRIER IS TO BE EQUIPPED WITH TIE TRUNK (SN233B).	11	1	J12345AA-1	L-5			
APPARATUS REQUIRED IN ADDITION TO LIST 7 WHEN CARRIER IS TO BE EQUIPPED WITH MESSAGE REGISTER INTERFACE (SN240).	12	1	J12345AA-1	L-6			

STOCK LIST					
LIST	QTY PER LIST	IDENTIFICATION	CODE	DESCRIPTION	NOTE
1	1	ED-1E456-70,G-4		CABINET ASSEMBLY	
1	1	844172643		COVER, LOWER REAR	
1	1	844172668		DOOR, LEFT REAR	
1	1	844172650		DOOR, RIGHT REAR	
1	1	844172437		PANEL, RIGHT REAR CONN	
1	2	H600-140,G-8		WIRE ASSEMBLY (-48V)	
1	125	900664871		SCREW, SEMS, 190-32X3/8 SHWH-TT W/LK-WSHA	
1	6	100203355	70D	FUSE 5 AMP (SPARE)	
2	1	ED-1E430-70,G-1		SENSOR, THERMAL ASSEMBLY	
3	1	ED-1E434-11,G16		UNIT CABLE	
3	1	H600-140,G-228		WIRE ASSEMBLY	
4	1	ED1E434-11,G-15		UNIT CABLE	
5	1	843636689		BRACKET, BATT	
5	1	401795299	KS-20390,L-7	PACK BATTERY	
5	1	H606-113,G-1		UNIT, CONN. & WIRE (BATTERY)	
5	3	840058242		SCREW PHM .112-40X1/4	
6	OMIT 1	844172643		COVER, LOWER REAR	
6	1	844176941		COVER, LOWER REAR	
6	1	403432818	T-4	BLOCK, TERMINAL	
6	4	840027049		SCREW, SHWH .216-24 X 1/2	
7	1	J12345AA-1,L-1		PORT CARRIER	
8	1	J12345AA-1,L-2		PORT CARRIER	
9	1	J12345AA-1,L-3		PORT CARRIER	
10	1	J12345AA-1,L-4		PORT CARRIER	
11	1	J12345AA-1,L-5		PORT CARRIER	
12	1	J12345AA-1,L-6		PORT CARRIER	

Appendix B. Hypothetical carrier drawing J1234AA-1

TABLE A - FEATURES							
			EQUIPMENT OR CIRCUIT DATA				
EQUIPMENT	LIST	QTY	EQUIPMENT OR CIRCUIT	LIST GROUP OR FIG	WRG	APP	NOTE
ASSEMBLY, WIRING AND EQUIPMENT FOR ONE PORT CARRIER	1	1 16 2	SD-1E557-01	18,19 2-17,24-31 22			
APPARATUS REQUIRED IN ADDITION TO LIST 1 WHEN CABLE ROUTING IS THROUGH THE OVERHEAD DUCT.	2						52
APPARATUS REQUIRED IN ADDITION TO LIST 1 WHEN CARRIER IS TO BE EQUIPPED WITH CONTACT INTERFACE (SN241).	3	1	SD-1E557-01 (CP ONLY)	9			
APPARATUS REQUIRED IN ADDITION TO LIST 1 WHEN CARRIER IS TO BE EQUIPPED WITH AUXILIARY TRUNK (SN231).	4	1	SD-1E557-01 (CP ONLY)	5			
APPARATUS REQUIRED IN ADDITION TO LIST 1 WHEN CARRIER IS TO BE EQUIPPED WITH TIE TRUNK (SN233B).	5	1	SD-1E557-01 (CP ONLY)	7		D	
APPARATUS REQUIRED IN ADDITION TO LIST 1 WHEN CARRIER IS TO BE EQUIPPED WITH MESSAGE REGISTER INTERFACE (SN240).	6	1	SD-1E557-01 (CP ONLY)	8			

STOCK LIST					
LIST	QTY PER LIST	IDENTIFICATION	CODE	DESCRIPTION	NOTE
1	1	844176453	132D	ASSEMBLY MOUNTING	
1	1	843629411		PANEL MARKED	
1	1	102712825	29A	BLOCK, FUSE	
1	2	400764627	KS-20289,L6C	RESISTOR 3920 OHMS	
1	6	100203355	70D	FUSE 5 AMP POS 7-9, 16-18	
2	1	845416502		PANEL, CONNECTOR (RT)	16
2	1	845416510		PANEL, CONNECTOR (LT)	16
3	1	103943361	SN241	PACK, CIRCUIT POS 0-3,5-8,13-16,18-21	
4	1	103943338	SN231	PACK, CIRCUIT POS 0-3,5-8,13-16,18-21	
5	1	103943353	SN233B	PACK, CIRCUIT POS 0-3,5-8,13-16,18-21	
6	1	103278792	SN240	PACK, CIRCUIT POS 0-3,5-8,13-16,18-21	

Appendix C. Revised hypothetical cabinet drawing J12345A-2

TABLE A - FEATURES							
			EQUIPMENT OR CIRCUIT DATA				
EQUIPMENT	LIST	QTY	EQUIPMENT OR CIRCUIT	LIST GROUP OR FIG	WRG	APP	NOTE
FRAMEWORK, ASSEMBLY, WIRING AND EQUIPMENT FOR ONE BASIC CABINET	1	1 1	SD-1E550-01 ED-1E456-70	 GR-4			60
APPARATUS REQUIRED IN ADDITION TO LIST 1 TO PROVIDE SEPARATE THERMAL SENSOR UNIT (SEE NOTE 55).	2	1	ED-1E430-70	GR-1			
INTRA CABINET CABLE ASSEMBLIES REQUIRED IN ADDITION TO LIST 1 FOR FIRST PORT CARRIER.	3						
INTRA CABINET CABLE ASSEMBLIES REQUIRED IN ADDITION TO LIST 1 FOR SECOND OR THIRD PORT CARRIER (MAX - 2 L-4).	4						
APPARATUS REQUIRED IN ADDITION TO LIST 1 TO PROVIDE 8 HOURS OF BATTERY RESERVE FOR T.O.D. CLOCK.	5						
APPARATUS AND WIRING REQUIRED IN ADDITION TO LIST 1 WHEN EXTENDED POWER RESERVE IS REQUIRED.	6	1	SD-1E552-01				62

STOCK LIST					
LIST	QTY PER LIST	IDENTIFICATION	CODE	DESCRIPTION	NOTE
1	1	ED-1E456-70,G-4		CABINET ASSEMBLY	
1	1	844172643		COVER, LOWER REAR	
1	1	844172668		DOOR, LEFT REAR	
1	1	844172650		DOOR, RIGHT REAR	
1	1	844172437		PANEL, RIGHT REAR CONN	
1	2	H600-140,G-8		WIRE ASSEMBLY (-48V)	
1	125	900664871		SCREW, SEMS, 190-32X3/8 SHWH-TT W/LK-WSHA	
1	6	100203355	70D	FUSE 5 AMP (SPARE)	
2	1	ED-1E430-70,G-1		SENSOR, THERMAL ASSEMBLY	
3	1	ED-1E434-11,G16		UNIT CABLE	
3	1	H600-140,G-228		WIRE ASSEMBLY	
4	1	ED1E434-11,G-15		UNIT CABLE	
5	1	843636689		BRACKET, BATT	
5	1	401795299	KS-20390,L-7	PACK BATTERY	
5	1	H606-113,G-1		UNIT, CONN. & WIRE (BATTERY)	
5	3	840058242		SCREW PHM .112-40X1/4	
6	OMIT 1	844172643		COVER, LOWER REAR	
6	1	844176941		COVER, LOWER REAR	
6	1	403432818	T-4	BLOCK, TERMINAL	
6	4	840027049		SCREW, SHWH .216-24 X 1/2	

UNIT REFERENCE TABLE					
UNIT CODE	LIST	QTY ALWAYS REQD	QTY FOR OPTIONS INDICATED	DESCRIPTION OF FEATURE OR OPTION	NOTE
J12345AA-1	1		MAX. 3	PORT CARRIER	52
J12345AB-1	1	1		COMMON CONTROL CARRIER	52
J12345AC-1	3	1		ALARM PANEL	58

Appendix D. Hypothetical carrier drawing J12345AA-2

TABLE A - FEATURES							
			EQUIPMENT OR CIRCUIT DATA				
EQUIPMENT	LIST	QTY	EQUIPMENT OR CIRCUIT	LIST GROUP OR FIG	WRG	APP	NOTE
ASSEMBLY, WIRING AND EQUIPMENT FOR ONE PORT CARRIER	1	1 16 2	SD-1E557-01	18,19 2-17,24-31 22			
APPARATUS REQUIRED IN ADDITION TO LIST 1 WHEN CABLE ROUTING IS THROUGH THE OVERHEAD DUCT.	2						52

STOCK LIST					
LIST	QTY PER LIST	IDENTIFICATION	CODE	DESCRIPTION	NOTE
1	1	844176453	132D	ASSEMBLY MOUNTING	
1	1	843629411		PANEL MARKED	
1	1	102712825	29A	BLOCK, FUSE	
1	2	400764627	KS-20289,L6C	RESISTOR 3920 OHMS	
1	6	100203355	70D	FUSE 5 AMP POS 7-9, 16-18	
2	1	845416502		PANEL, CONNECTOR (RT)	16
2	1	845416510		PANEL, CONNECTOR (LT)	16

CIRCUIT PACK TABLE						
DESCRIPTION	CODE	COMCODE	CARRIER POSITION	FIG	OPT	NOTES
CONTACT INTERFACE	SN241	103943361	POS 0-3,5-8,13-16,18-21	9		
AUXILIARY TRUNK	SN231	103943338	POS 0-3,5-8,13-16,18-21	5		
TIE TRUNK	SN233B	103943353	POS 0-3,5-8,13-16,18-21	7	D	
MESSAGE REGISTER INTERFACE	SN240	103278792	POS 0-3,5-8,13-16,18-21	8		

Biographies (continued)
in materials engineering from the Massachusetts Institute of Technology, Cambridge. Mr. Clancy is responsible for working with internal AT&T customers to ensure satisfaction with IMS products and services. He has a B.S. in electrical engineering from the Polytechnic Institute of New York, Brooklyn; an M.S. in industrial engineering (operations research) from Lehigh University, Bethlehem, Pennsylvania; and an M.S. in computer science from Rutgers University, New Brunswick, New Jersey. He joined AT&T in 1965. Mr. Lindemulder is responsible for the physical design of the Definity Generic 1 switching equipment and apparatus. He joined AT&T in 1960 with a B.S.M.E. from New Mexico State University, Las Cruces; and an M.M.E. from New York University, New York. Mr. Kinney is responsible for developing process and business software systems, and for manufacturing process engineering. He holds a B.S. in technical management from Regis College, Denver, Colorado, and joined AT&T in 1970.

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