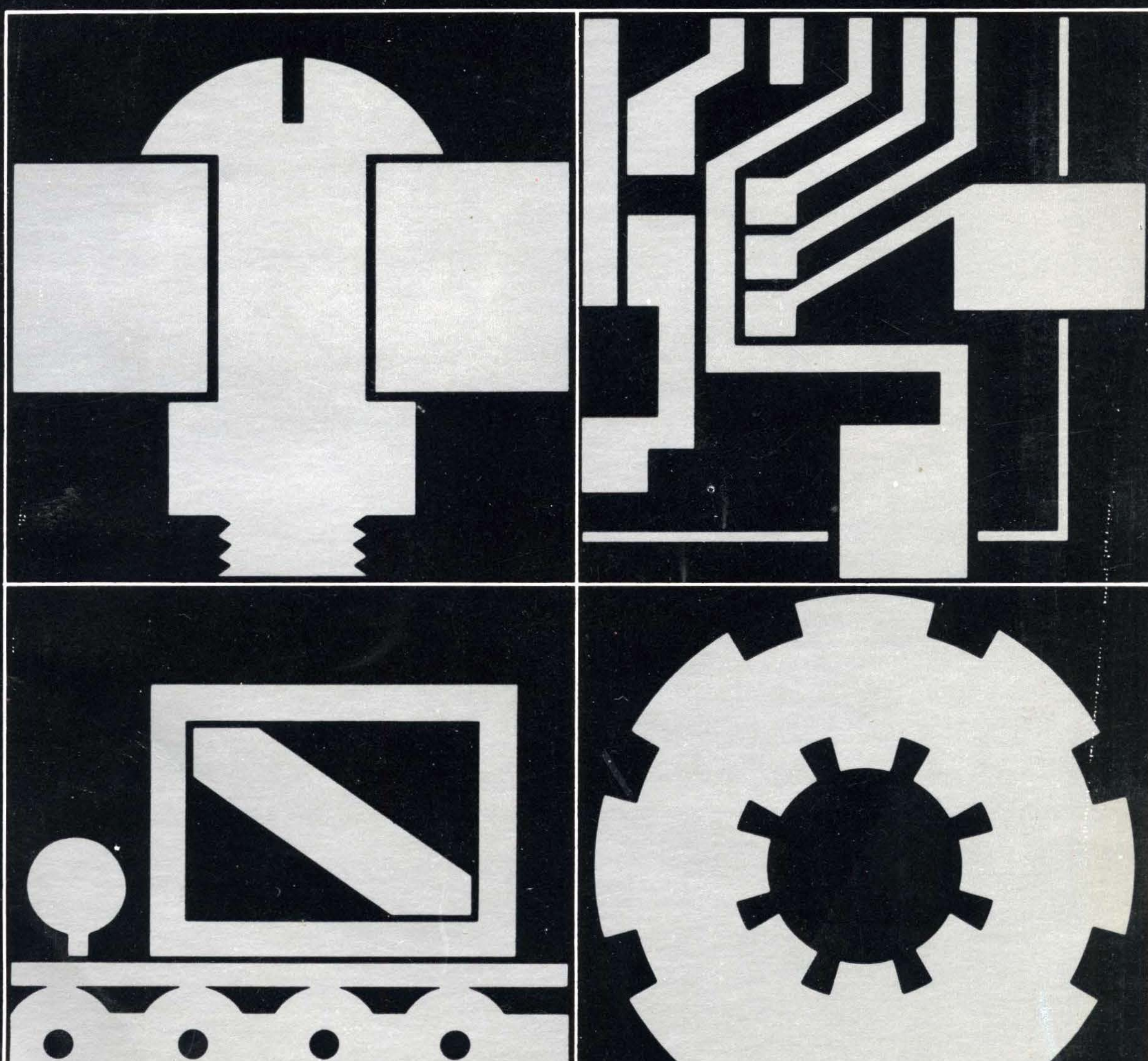
IBM

Communications Oriented Production Information and Control System

Volume I

Management Overview
System Requirements
Glossary
Index



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Foreword

COPICS (Communications Oriented Production Information and Control System) is a series of concepts that outline an approach to an integrated computer-based manufacturing control system. The concepts deal with problems common to most companies, from a forecast of customer orders, through development of the master production schedule, to production and shipment of the product. COPICS is involved, therefore, with allocation and control of most of the major resources of a company – plant, equipment, manpower, and materials.

COPICS evolved from the approach to manufacturing applications presented in the IBM publication *The Production Information and Control System* (GE20-0280). In COPICS those applications are defined from a communications point of view and have been expanded in scope.

The twelve COPICS chapters provide management with a guide for development of a dynamic online manufacturing control system that is terminal and communications oriented and event responsive. The chapters present the system's concepts in a manner designed to help develop a system that can truly respond to the requirements of all levels of operating personnel and management. Little knowledge of computers is assumed, although some prior exposure to computer concepts and familiarity with such terms as "program", "files", etc., is helpful. Emphasis is on what the problems are and *why* their solution is valuable. How specific problems are solved is discussed only at that level of detail required to assure managers that the solution is feasible. The computer is not, itself, the system, but is, rather, a tool to be used by the manager.

The COPICS concepts are oriented to production and related manufacturing applications. They are not concerned directly with other major areas, such as finance, marketing, and personnel, although the COPICS approach collects data that will be helpful to these areas.

Throughout the COPICS publications, distinction is made between a given COPICS concept, the corresponding chapter, and the corresponding plant department by the use of small capital letters, italics, and initial capital letters, respectively. For example, reference may be made to the COPICS concept PURCHASING AND RECEIVING, or to material in *Chapter 10, Purchasing and Receiving*, or to the plant departments called Purchasing and Receiving.

The complete system is presented in eight volumes containing, in all, 17 sections. The Management Overview section is also available as a separate publication, G320-1230. The contents and IBM order numbers of the eight volumes are as follows:

Volume I	G320-1974	Management Overview, System Requirements, Index, Glossary
Volume II	G320-1975	Chapter 1 Engineering and Production Data Control
		Chapter 2 Customer Order Servicing
Volume III	G320-1976	Chapter 3 Forecasting
		Chapter 4 Master Production Schedule Planning
Volume IV	G320-1977	Chapter 5 Inventory Management
Volume V	G320-1978	Chapter 6 Manufacturing Activity Planning
		Chapter 7 Order Release
Volume VI	G320-1979	Chapter 8 Plant Monitoring and Control
		Chapter 9 Plant Maintenance
Volume VII	G320-1980	Chapter 10 Purchasing and Receiving
		Chapter 11 Stores Control
		Chapter 12 Cost Planning and Control
Volume VIII	G320-1981	System Data Base

To obtain the complete set of eight volumes please order the IBM Bill of Forms number GBOF-4115.

Management Overview

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Introduction

The Communications Oriented Production Information and Control System (COPICS) is a series of concepts that outline an approach to an integrated manufacturing system. The concepts deal with problems common to most manufacturing companies, from a forecast of customer requirements, through development of the master production schedule, to the production and shipment of the product. COPICS is involved, therefore, with allocation and control of most of the major resources of the company – plant, equipment, manpower, and materials.

The following chapters describe the COPICS concepts. A systems design is presented on the concept level, and COPICS provides a framework for the development of integrated applications.

The COPICS approach outlines solutions to business information processing and communications problems caused by the constant changes managers must face. The discussion identifies areas where computers can be profitably applied to improve the company's operations. It emphasizes the computer's role in opening up new approaches to critical operating problems, rather than merely speeding up existing procedures.

Scope of the system

COPICS is concerned with those manufacturing control methods that can be profitably implemented with computers today. It shows how a powerful man-machine relationship can be created. The computer is not, itself, the system, but rather a tool used by the manager.

The application descriptions are written for all levels of management.

- Their presentation is *management-oriented,* not data-processing-oriented.
- They cover all *production and related applications.*
- In each application they emphasize the use of *data communications technology.*
- They are applicable to *nearly all types of manufacturing industries.*

The intent throughout is to remove some of the mystery surrounding computer-based manufacturing applications. Little knowledge of computers is assumed, although some prior exposure to computer concepts and familiarity with such terms as "program", "files", etc., is helpful. Emphasis is on *what* the problems are and *why* their solution is valuable. *How* specific problems are solved is discussed only at that level of detail required to assure managers that the solution is feasible.

management-oriented

production-oriented

The COPICS concepts are oriented to production and related manufacturing applications (Figure 1). They are not concerned directly with other major areas such as finance, marketing, and personnel, although the COPICS approach collects data that would be helpful to these areas.

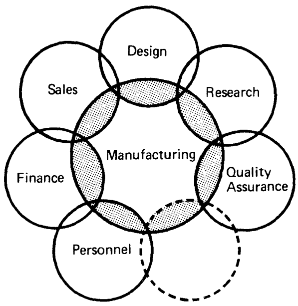


Figure 1. COPICS is oriented to production and related applications and provides data to other major areas

The system concepts are presented in a manner designed to help production and data processing personnel develop a system that can meet their company's needs and thus be truly responsive to both management and user requirements.

The application areas outlined in the COPICS concepts, as illustrated in Figure 2, can be summarized as follows:

- ENGINEERING AND PRODUCTION DATA CONTROL creates and maintains basic engineering records.
- CUSTOMER ORDER SERVICING links the sales information system to manufacturing. Customer order entry and control of the order through to shipment are addressed.
- FORECASTING provides techniques to project finished product demand and establish management standards to control manufacturing activity.

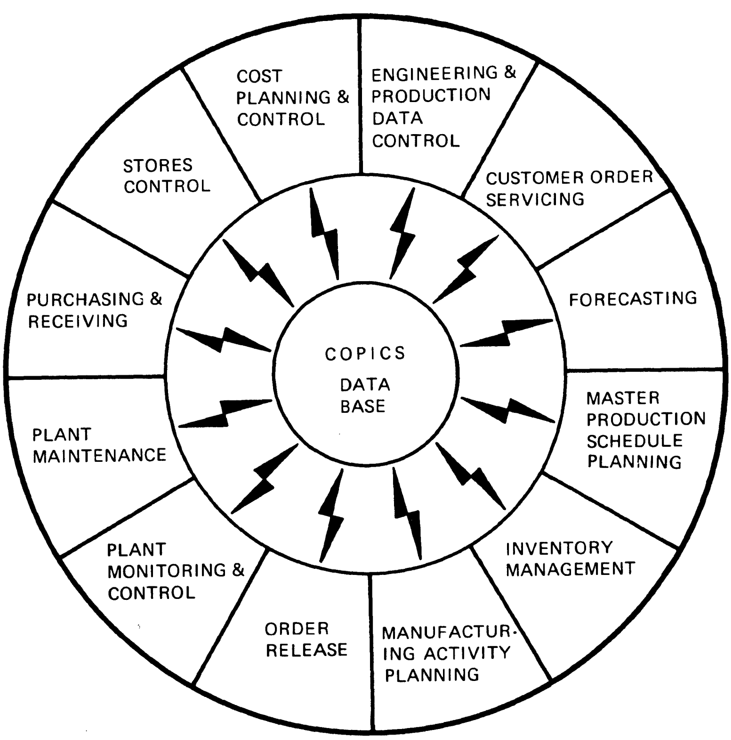


Figure 2. The applications covered by COPICS

- MASTER PRODUCTION SCHEDULE PLANNING allows quick assessment of the impact of alternate production plans on plant capacity. The result is a realistic master production schedule, which is used for further detailed planning.
- INVENTORY MANAGEMENT determines the quantities and timing of each item to be ordered – both manufactured and purchased – in order to meet the requirements of the master production schedule.
- MANUFACTURING ACTIVITY PLANNING is used to plan detailed capacity requirements and to adjust the date of planned order release to be consistent with plant capacity. Its objective is to achieve a reasonably level load as well as to minimize work-in-process inventory and manufacturing lead time.
- ORDER RELEASE is the connection between manufacturing planning and execution. On the planned order release date, this function creates the documents authorizing production or purchase of the required material.
- PLANT MONITORING AND CONTROL traces the progress of each shop order as it moves through the shop. It coordinates many of the supporting activities, such as inspection, materials handling, and tools. Direct computer control of many phases of the manufacturing process also falls here.
- PLANT MAINTENANCE addresses maintenance manpower planning, work order dispatching and costing, as well as preventive maintenance scheduling.
- PURCHASING AND RECEIVING maintains current purchase quotations, creates purchase orders, and follows the progress of the order from the time of requisition, through acknowledgment, follow-up, receipt, quality control, and deposit in stores.
- STORES CONTROL keeps track of material location and determines where to store new material. Its objectives are to increase utilization of storage space and to reduce both picking time and picking errors. Automated warehousing techniques are also addressed.
- COST PLANNING AND CONTROL is addressed particularly to the financial executive and provides techniques whereby the information created and maintained for production purposes can be used for budgeting and accounting applications.

The application descriptions are supported by two other sections:

- *System Requirements* outlines some of the more important items management should consider when installing a communications-based system of this magnitude. It is recommended reading for all managers.
- *System Data Base* describes many of the data elements required by the system and one approach to organizing them. It should be used as a guide to data base design.

Not every company will necessarily want to implement all sections of COPICS. Applicability will depend on the type of manufacturer, product line, size of plant, etc. The system design, however, permits companies to select an approach and configurate a system tailored to their particular needs.

communications-oriented

Today a manufacturing company is successful in proportion to its ability to rapidly gather, transmit, and interpret all information describing its activities. The complexity and amount of data needed for the conduct of the business have increased considerably, yet most companies have not changed their manufacturing control systems appreciably. *Many managers are trying to control more complex business activities with information that becomes increasingly incomplete and out of date.*

COPICS brings a new approach to this problem by employing the communications capability of the computer to help management operate more effectively. The emphasis throughout is on the use of communications equipment – display terminals, shop floor terminals, etc. – at the tactical level, to help communicate management policy, and at the operational level, to monitor and control the actual operating activities.

industry-wide

Although applicable mainly to manufacturing companies, the concepts presented here apply also to industries whose main functions are in other areas. Railways, airlines, and telephone companies, for example, may maintain facilities for producing maintenance parts and reconditioning equipment. The types of industries to which the COPICS concepts are addressed are shown in Figure 3.

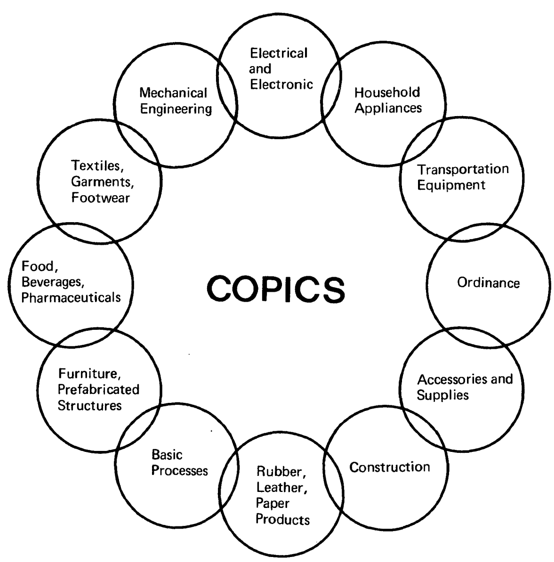


Figure 3. COPICS is applicable to many types of industry

COPICS is designed to assist the manager in his day-to-day operations. It is not enough for a system to be technically and economically sound; it must be designed for the people who use it, and these people must become involved in its design to make sure they get what they need. The satisfaction of the system user must always remain the primary objective.

The COPICS concepts outline a communications-oriented planning, implementation, and control system, and this section highlights some of the systems design features that will help managers in:

- *Planning*, which involves choosing between alternatives.
- *Implementation,* which starts by breaking down broad plans into more detailed plans. The system indicates when adjustments to these plans are needed, and it facilitates taking care of such adjustments.
- *Control,* in which actual conditions are monitored and measured against standards to make sure everything is going according to plan. When deviations from the plan occur, the system automatically notifies the responsible manager.

Figure 4 illustrates the levels of management and business functions that COPICS addresses. The relationship of each of the application areas to these functions is shown in Figure 5.

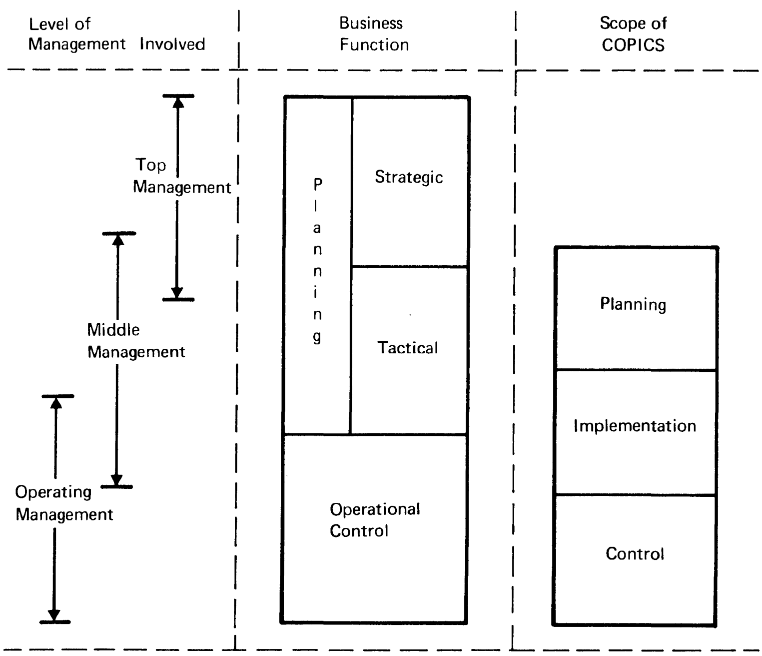


Figure 4. The management level and business functions addressed by COPICS

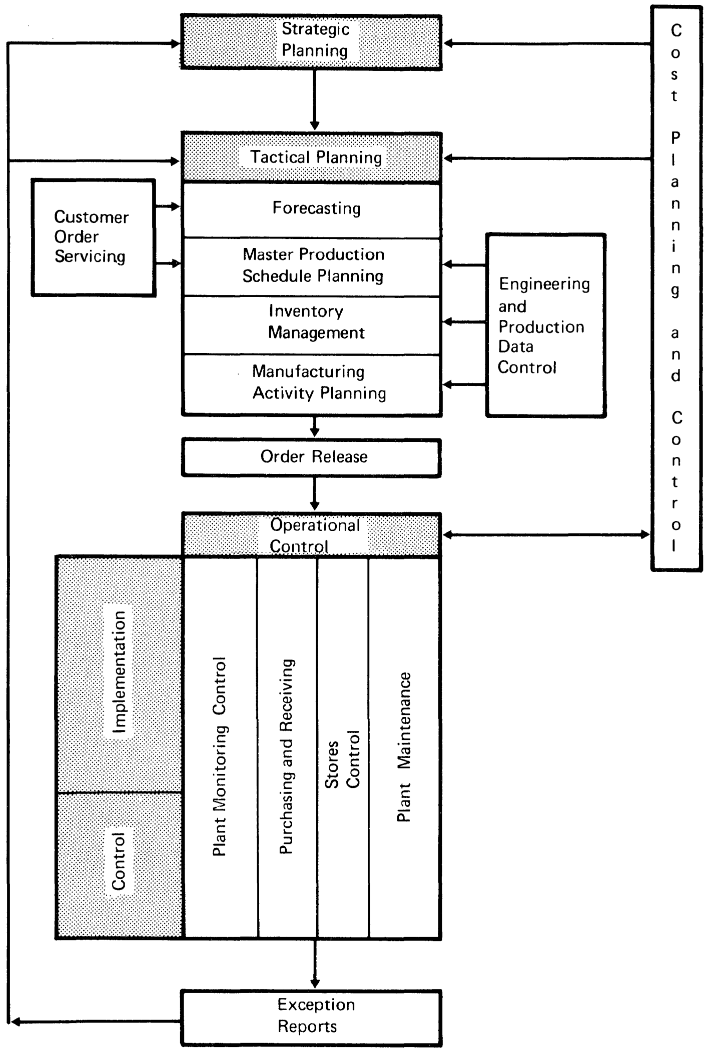


Figure 5. The relationship of the application areas to the business functions

Planning

The planning process begins with the setting of objectives. Strategies, policies, and standards, usually involving the allocation of resources, must be defined to meet those objectives. Business planning is concerned with both *strategic planning* and *tactical planning.*

strategic planning

Corporate strategic planning is not directly addressed by COPICS. Strategic decisions are normally influenced more by outside economic factors than by internal factors. COPICS, however, provides much of the internal information that will assist in making these decisions.

tactical planning

COPICS applies primarily to tactical planning. This function is shared by top and middle management and involves such activities as setting manpower levels, determining production schedules, and stating inventory policy. Tactical planning should result in a series of logical rules to govern day-to-day operating decisions.

Simulation as a planning tool

Planning is nothing more than choosing from a range of alternatives. One method of testing alternatives is called simulation. The data maintained by COPICS and its system techniques permit a wide range of questions to be answered through simulation – for example:

- How will changing a component affect product cost?
- How much will a new machine reduce manufacturing costs?
- If the planned work queue at certain machine centers is reduced, how much will manufacturing lead time be reduced?

Another type of simulation results in *tradeoff,* or *exchange, curves.* These allow management to assess the effect of a policy decision before it is put into effect. Figure 6, for example, shows the increase in inventory that will result from increasing service to customers. In this example, if 95% of all customer orders are filled on demand, a finished goods inventory of 1.4 million must be maintained. A 98% service level will require an investment of 2 million – an increase of over 40%.

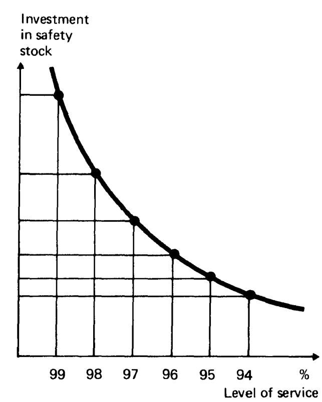


Figure 6. An example of a trade-off curve

Further types of simulation have to do with commitment of production resources to specific orders. For example, a planner can test the impact of alternate master production schedules on production facilities and have the result in minutes. This type of simulation does not involve costly development of complicated mathematical models. In most cases it can utilize the computer programs used in normal manufacturing planning.

Implementation

Once the production plan for finished products (that is, the master production schedule) has been established, its implementation results in purchase orders and shop orders. Alterations to the plan can be quickly processed and transmitted to operating personnel. Effective implementation of the plan is helped by features such as:

- The ability to test the detailed effect of a single significant order on production capacity. This allows realistic confirmation of order delivery dates.
- Engineering change procedures that ensure implementation of the changes at the proper time. The result is lower component part obsolescence and fewer production shortages.
- Procedures to check that all required materials and tools are available before an order is released to the shop floor. This eliminates costly physical staging to check for shortages.
- Tool control and recall procedures that reduce shop order delays caused by tool shortages, ensure maximum tool usage before recall, and reduce scrap caused by worn tools or uncalibrated gauges.
- Work dispatching and manufacturing activity reporting procedures which ensure that the operator works on the jobs assigned to him in the correct sequence.
- Purchase order procedures that reduce the amount of time between requisitioning and order release. At time of receipt, rush orders are automatically handled on an expedited basis.

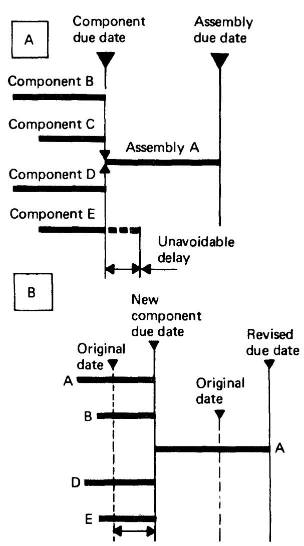


Figure 7. If one component is delayed, all components can be similarly delayed

Production systems require rapid implementation of changes to the plan. For example, the delay of a component order can have far-reaching effects, which must be quickly communicated to production and purchasing departments so as to change priorities of related orders (Figure 7). COPICS can determine the effect of a component order delay and dispatch messages altering the priorities of orders in the other affected departments so that components not yet needed will not be produced. It can also report which, if any, customer orders will be delayed.

Speed in implementation of production plans is also important when interrelated plants are geographically separated. In such cases, coordination problems caused by delay are greatly increased. Because of periodic planning and communication delays, a revision to the plan may take weeks to put into effect throughout the entire plant complex. Data transmission between computers, along with the system's *net change* capability, can reduce the replanning cycle to hours or days.

The ability to move data quickly between plants and warehouses has significant advantages. Remote locations can quickly exchange information about shortages, and inventory can be shifted from one location to another. This can mean that less inventory has to be carried in each warehouse, as slow-moving items can be stored centrally and still be supplied quickly.

implementing policy adjustments

Another important feature emphasized by COPICS is the ability to make policy adjustments easily. For example:

- Manpower idle time can be minimized by modifying a factor that governs the planned queue of work at each machine center.
- Part shortages can be controlled by altering factors that determine the amount of safety lead time allowed.
- Emergency downtime can be minimized by altering the factors used to calculate the preventive maintenance time interval.

Control

Most managers would agree that if they could more closely monitor the activities under their control, they could achieve better performance. Unfortunately, an individual's span of attention and control is limited. The system, however, can monitor a large number of widely dispersed activities and issue an "alarm" when conditions require management intervention, as when:

- A purchase order fails to arrive on the delivery date specified
- A bottleneck production facility goes down
- An excessive amount of scrap is reported
- A work center is about to run out of work

Alarms of these types can be generated as a result of normal manufacturing activity reporting. For proper action to be taken in response to such out-of-line situations, two "control aids" are needed:

- *A set of standards* against which activity can be compared by the system to see if an abnormal condition exists
- *Action Files,* which are used by the system to direct the alarm message to the person who can correct the off-standard condition

These two requirements are general in nature and apply to all areas of COPICS, even if not specifically mentioned in a given chapter. The development and use of measurement standards and Action Files is summarized in the following paragraphs.

measurement standards

Standards are used both to measure performance and to provide an incentive. Standards pertain to such things as production labor, sales quotas, and budgets. Standards development, however, should also be extended into other areas, such as scrap allowances and work center queues. Lack of effective standards explains why control is the weakest part of many existing business systems.

COPICS can help develop effective measurement standards for many business areas. Such help is valuable because establishing and maintaining the large number of standards required is a sizable job.

action files

The second requirement for effective control under COPICS is the Action File (see Figure 8). Once an out-of-line condition is detected, two questions arise: What should the appropriate response be? and Who should take action? In a system such as COPICS, the answers to these questions are predetermined. The Action File provides an inventory of required types of action. The computer consults the Action File whenever an off-standard condition arises, to determine what message is to be transmitted, and to whom.

Further use of Action Files provides a number of functions and advantages:

- The Action File places open requests in priority sequence so that important items are handled first.
- People are notified in the proper sequence.
- The system is assured that the responsible person has been notified, because the message is automatically routed and the recipient must normally identify himself and acknowledge receipt of the message.
- By modifying certain coding in the system's records, a manager can specify how much information he wishes to receive and how much control to exercise.

Continuous monitoring of performance by COPICS, together with effective standards and fast communication of "alarm" conditions, provides early warning of out-of-line situations. The earlier the warning, the better the chance of avoiding costly corrective procedures. *Historical reports, pointing out past mistakes, are an expensive form of control.*

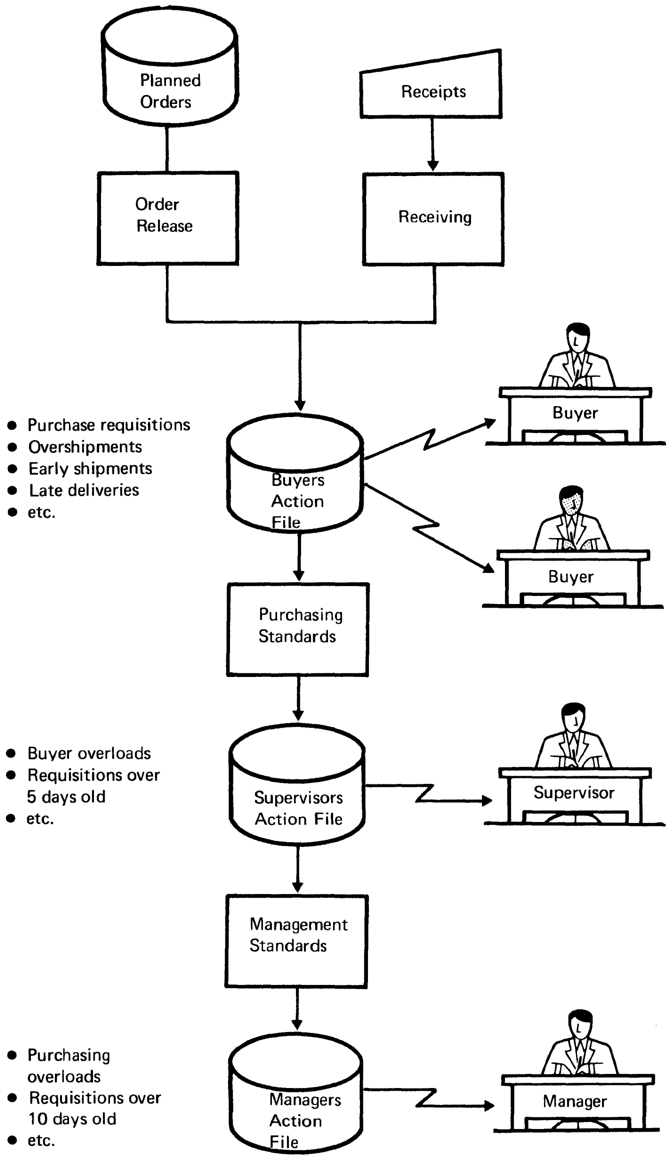


Figure 8. Example of Action Files used to direct alarm notifications and requests for specific action to the responsible employee

Direct computer monitoring and control

In many cases, the computer can be attached, via instrumentation, directly to the production process. When attached to facilities such as machine tools or stamping presses, it can monitor the actual production rate, operating conditions, etc. Such techniques provide the closest possible control over production variations and instant response to out-of-line situations.

Computers can also be attached directly to automated production facilities such as heat treatment plants or foundry processes. In such cases, operating conditions are monitored, and, via controlling instrumentation, the computer can quickly adjust temperatures, pressures, and feed rates. These techniques result in significant increases in productivity and product quality.

Other areas of direct computer control discussed in COPICS include testing equipment, conveyor control, and high bay warehouse (stacker crane) control.

COPICS places special emphasis on three characteristics that today's manufacturing control systems should possess in view of the rapidly changing business environment:

- *Adaptability to change.* The system is designed for ease of adapting to changes in business objectives, organization, or application approaches (Figure 9). This is achieved primarily through a flexible *data base.*
- *Reduction of delay.* Information bearing on the production plan updates affected records at the earliest point in time. This *real-time* processing capability, coupled with a *net change* approach to replanning, reduces delay in implementing changes and minimizes their impact.
- *Usefulness to management.* COPICS is management-oriented and places heavy emphasis on providing managers with useful information in meaningful form.

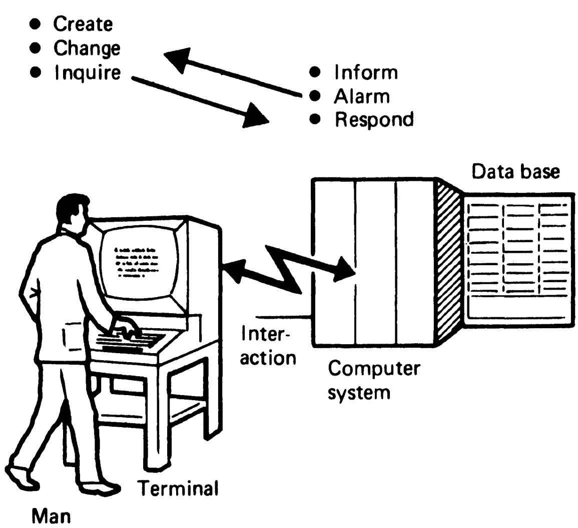


Figure 9. Emphasis is placed on how man interacts with the system

Adaptability to Change

It could be said that many companies remain successful not *because* of their systems but *in spite* of them. Their systems are static in that they are not redeveloped, expanded, or refined, even though the business environment changes and new problems arise. It is highly desirable that production planning and control systems change with changing conditions, if they are not to deteriorate in usefulness. Some of the changing conditions they must keep up with are:

- Revised business objectives because of changed market conditions
- The introduction of new products
- Availability of new management tools, such as data processing and communications technology
- Changes in the company organization
- Changes in management personnel, often accompanied by a different style of management

Admittedly, it is often difficult and expensive to change today's systems, but this is partly due to the way current systems have been designed.

Changes to the system

One particular type of change that can cause major disruption and expense is the required alteration of many existing computer programs whenever the basic data in the system's files must be modified or extended for new applications. In many companies the cost of program maintenance exceeds that of developing new applications (Figure 10). This problem can be solved by the creation of a data base that is common to, but independent of, application programs.

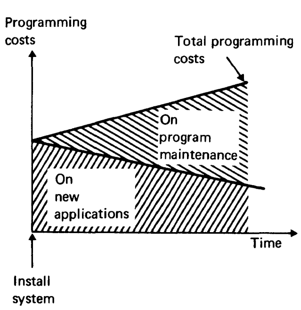


Figure 10. New application progress is often slowed by the cost of maintaining existing programs

Data base

COPICS is built around a *data base* creation and maintenance system that permits inexpensive file reorganization when system changes occur. Data can be reorganized without incurring the significant expense of modifying existing programs that will have to use the new files. Because this technique significantly reduces data duplication, it also leads to reduction in data storage and maintenance costs as well as computer processing time.

In addition, the cost of implementing new applications is greatly reduced, because application programs become simpler and easier to write. This is so because data retrieval procedures, formerly the task of each application programmer, are essentially taken over by the data base system itself. Thus the application program remains unaffected when files are reorganized. This flexible data base approach is essential to the success of an integrated system such as COPICS.

Reduction of Delay

COPICS employs two approaches that significantly reduce delay in determining the impact on the production plan of day-to-day changes and interruptions:

- *Real-time* data processing, in which most data required by the system is entered into it at the point where the data is created and at the time it is created, so that the affected records may be immediately updated.
- *Net change* processing, in which any effect that data entered into the system may have on the production plan can be quickly determined. Replanning no longer has to take place just once a week or once a month. Instead, it can be done once a day or, in some instances, continuously.

Real-time processing

Processing data in *real time* means that:

- Data is transmitted *online,* that is, by means of terminals linked directly to the computer.
- The records concerned are *updated immediately* after the transaction occurs.
- The system responds (if a response is required) without delay.

online processing

Online processing requires the use of terminals (Figure 11) at the point where data originates, plus data transmission facilities (for example, telephone lines) to move the data to the computer.

Online data entry eliminates the need for human intervention between the point of data creation and the computer system. For example, when an employee reports completion of an operation, the data (man number, shop order number, and quantity completed) is sent direct from a terminal in the employee's department, via data transmission lines, to the computer's memory. There is no intermediate data handling step, and no paperwork is created.

immediate updating

For immediate updating of the record, most data files that are to be updated must be stored on direct access devices, such as disk files. These allow fast access to whatever record is to be updated.

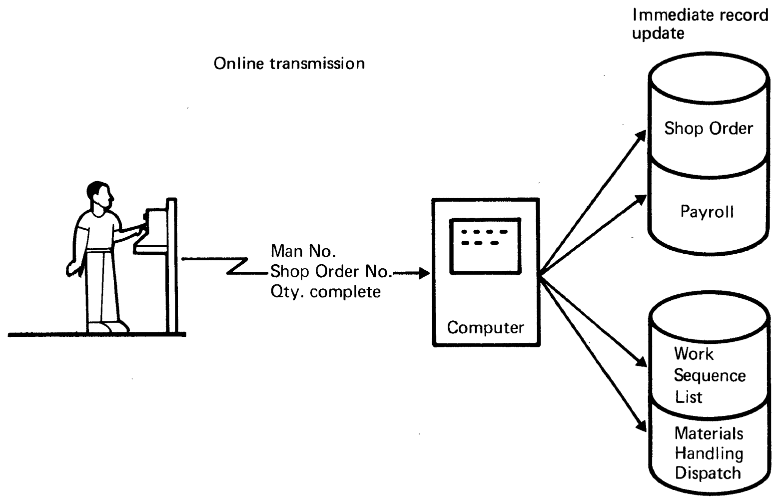


Figure 11. Online processing involves direct entry of data into the computer from a terminal, an immediate updating of the records concerned, and a no-delay system response

In the example above, the transaction updates all records concerned, in this case:

- Shop order record, which reflects job status and accumulated labor and material cost to date
- Work queue at the completing work center (indicating how much work is waiting for each machine), in order to remove the job from this center's backlog
- Next center's work queue list, in order to signal that the job will be arriving shortly
- Materials Handling Action File, in order to indicate that the material is ready to be moved to the next work center
- Employee's payroll record

system response without delay

Because data is entered at the time of the event and record updating proceeds immediately, the system is in position to respond without the usual delay inherent in periodic batch processing.

Not every transaction requires a system response. For example, a stock receipt is posted to the inventory record and, in the absence of special circumstances, no response is required. Other transactions will trigger a response by the system. The updated record forms the basis on which the system determines whether a response is required. System responses normally take the form of reports, alarm messages, and requests for specific action, as discussed previously under "Action Files" (also see Figure 8).

With real-time processing, there need be no delay in system response. The message is not necessarily instantaneous – its "immediacy" is relative to the user's need.

Net change processing

With most of today's manufacturing control systems, alterations to the production plan are made on the basis of a weekly or monthly cycle. This would reduce many of the advantages of real-time processing. COPICS introduces approaches that allow changes in the plan to be processed at any time.

For example, the effect of a change in the master production schedule, excess scrap, or an engineering change can be determined when it happens – not at the end of the week or month. The system quickly notifies management of the need for any changes in order due dates or in planned capacity. The subject of *net change* is discussed primarily in *Chapter 5, Inventory Management.*

batch processing

Not all data need be processed immediately. In some cases delays can be tolerated. In these instances the application approach is batch processing. COPICS illustrates where real-time processing is profitable and where batch processing can be employed.

The following are some of the conditions under which batch processing is appropriate:

- When the review frequency is fixed by law or by custom, as in the case of weekly payroll or monthly accounting statements.
- When large amounts of different data must be considered before making a decision. For example, the completion date for one order cannot be estimated unless all other orders competing for the same production equipment are considered at the same time.
- When data must be accumulated over a period of time. For example, performance may be measured by comparing the current period's activity with that of the previous period or the same period last year. In this case, there is little need to update the current period's activity on a real-time basis.
- When computer equipment and support would be excessively costly. This is the reason most commonly cited by business systems specialists for continuing with batch processing. It is a major consideration. However, advances in computer equipment performance, lower prices, and more comprehensive support programs have brought real-time processing within the reach of most companies.

Benefits of real time and net change

The benefits that result from processing data in real time and processing only changes to existing plans rather than entire new plans are as follows:

- Fast reaction to problems
- Reduction in inventory and workload fluctuation caused by communication delays
- Reduced data acquisition costs

fast reaction to problems

One of the historical claims of computer-based systems is that they reduce processing time. This is normally achieved by attacking only one portion of the problem – processing the data. Figure 12 illustrates the effect that real-time processing can have on the total information processing cycle. Although the computer is very fast, getting the information to and from the computer can be slow.

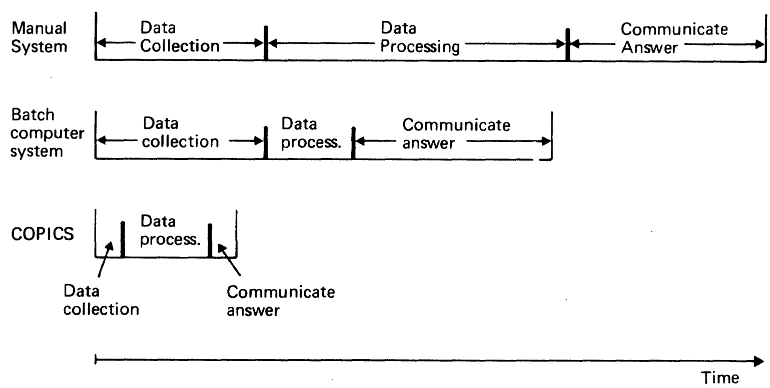


Figure 12. Real-time processing reduces two major causes of delay: collecting data and communicating the answer

In real-time processing, the processing/answer cycle may cover only a few seconds or minutes, as opposed to days in most conventional batch systems. This is the most significant feature of real-time processing, because there are so many situations in which delay is costly – for example:

- When a decision made in one area of the business may quickly affect other areas.
- Where alterations to plans must be implemented quickly because of frequent changes in business volume.

- Where there are geographically dispersed production facilities that must be closely coordinated.
- Where a decision is based on a series of questions and answers, and each question is based on the preceding answer.

reduction in fluctuation

Another major advantage of real-time processing in many manufacturing application areas is that it can prevent the fluctuations in business operations so often caused by delays in information processing.

Fluctuation in many factors affecting manufacturing operations is inherent in business. Examples are customer demand, labor attendance, work-in-process, vendor delivery times, etc. While a certain amount of fluctuation is due to the nature of business and cannot be avoided, such fluctuation can be *amplified* as a result of lags in the information flow.

Research has shown that a change in the rate of demand at a retail level will eventually be reflected, temporarily magnified, at the factory level. The amplitude of the excess fluctuation in the demand on the factory is in proportion to the lag in communicating the event through the consumer-retailer-wholesale distributor-manufacturer chain.

For instance, if consumer demand falls off 5%, the retailer's conventional inventory control system will be slow in reacting to this; his forecasting and reordering practices will continue unchanged until some inventory excess develops. To compensate, he will then have to reduce his reorder quantities, but by then a mere 5% reduction would not provide for using up the accumulated excess. He will, therefore, cut his orders drastically.

At that point, the wholesale distributor will experience reduced demand, but of a larger magnitude. Before his system responds to the change, he will be accumulating excess inventory. Eventually he will have to compensate by curtailing his demand on the manufacturer, by a larger percentage than the percentage reduction of demand that he experienced.

The plant now experiences a large reduction in customer demand. If it carries finished goods inventory, it will have to work off the surplus and curtail production. A 5% reduction would have been sufficient, if it had been instituted at the time consumer demand fell off. But while that demand ran at 95%, the plant kept producing at 100%, *because of a lag in the information flow.*

The swing in the demand cycle is in direct proportion to the delay in recognizing the original problem (Figure 13).

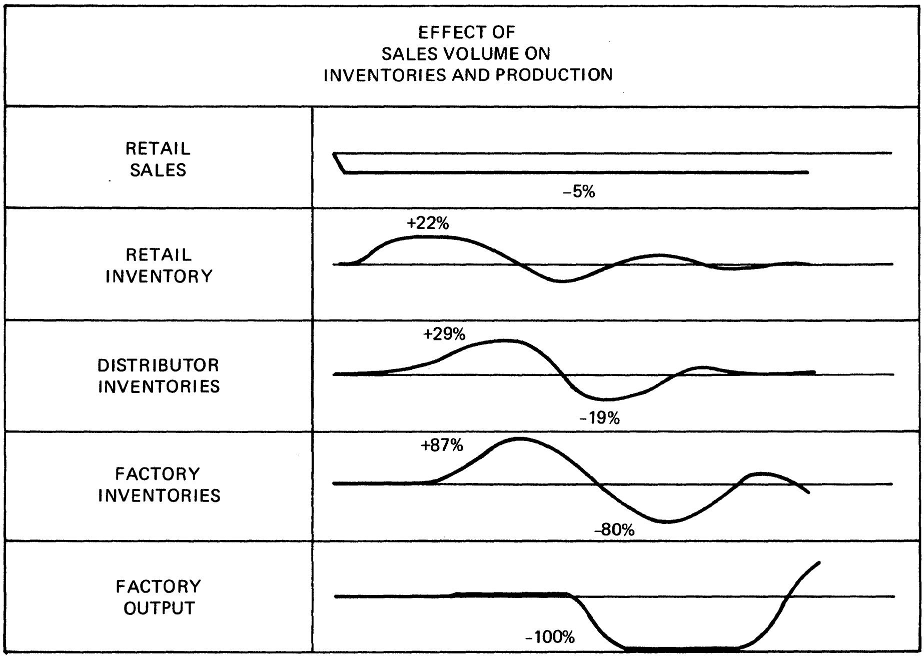


Figure 13. Delay in recognizing a change can cause wide swings in business cycles

Business Buffers. The cost of fluctuation in a variety of factors affecting business operations is not easily determined. Most manufacturing managers would agree, however, that costs could be significantly reduced if demand on production facilities were more level, since this would mean smaller buffers to absorb fluctuations.

Buffers occur in many ways. For example:

- Finished product inventory is used to absorb fluctuations in customer demand.
- Early order due dates are specified to allow for fluctuations in vendor delivery.
- Extra pieces are started in case the scrap rate runs too high.
- Work-in-process queues are built up as a guard against fluctuations in work arrival rates.
- Additional machine capacity is acquired to absorb fluctuations in machine downtime.

Early reaction through real-time processing reduces fluctuation and thus *enables these buffers to be significantly decreased.*

Cost reduction is accomplished by real-time processing in three ways:

reduced data acquisition costs

- *The amount of data to be entered into the system is reduced.* For example, when reporting a completed manufacturing operation, the employee need enter only a plastic badge (identifying himself to the system), the quantity completed, and a transaction code indicating completion of the job he was previously assigned. This contrasts sharply with the amount of data reported with conventional methods.
- *Paper handling is reduced.* COPICS procedures eliminate many pieces of paper, such as labor cards, material and tool requisitions, etc. Where a copy is required as a reminder of the job assigned (for example, a material move ticket), it can be printed by the system just before it is needed. Thus it is easy to incorporate last minute changes. Because the system maintains its own audit trail, the paper can be discarded after use.
- *The number of errors on data entry is significantly reduced.* Real-time processing allows notification of an error condition while the employee is still at the terminal. Correction can be made while the event is still in the operator's mind. *System Requirements* compares batch and real-time error control in more detail.

Usefulness to Management

COPICS is designed to aid manufacturing management in four basic ways:

- It enables management to determine the effect of alternative plans, such as different master production schedules, before one of them is implemented. These *simulation* techniques are addressed in each of the application areas.
- It enables all areas of the business to be informed much sooner of the effect of a given event. Thus, everyone "changes direction" at the same time, and much effort can be saved.
- It provides *more direct management control.* For example, management can control the level of inventory by policy decisions that will influence plant capacity, order size, and safety stock.
- It reduces the amount of repetitive, tedious monitoring and decision making that management must otherwise engage in. Many reports and urgent phone calls are avoided. The system can quickly notify the responsible manager when something is not going according to plan, and it provides the information on which he can make the needed decision. He has the ability to *inquire into the system* at whatever level of detail is necessary to make a decision.

The management of change

A true gauge of management ability is success in exploiting opportunities, and this usually involves rapid response to change. Advancing technology has brought new products at an accelerating rate, shifts in the economy cause wide swings in the rate of customer orders, competition alters prices, important machines break down, etc. These things are not unique; they are normal events in a manager's life. They impose on all managers an essential function: the management of change itself.

Fortunately, the same technology that causes accelerated change also provides a means to help respond to it – the computer. Rapid advances in the use of the computer as a communication tool have provided the basis on which COPICS is established.

COPICS addresses some of the most important issues and problems facing manufacturing management today. Its primary purpose is to present an economical, feasible solution that can be easily adapted to specific situations of prospective COPICS users.

COPICS represents a master plan for the implementation of a comprehensive manufacturing control system. It is meant to provide a framework for application development in twelve functional areas.

Need for Application Framework

Most of today's manufacturing control systems have been developed independently of the other systems with which they have to interface. In fact, Production, Accounting, Sales, Engineering, etc., all have typically developed their own systems autonomously, with the intent of solving their own specific problems rather than those of the whole company. The unrelated and incompatible systems that result make comparison between various areas of the business difficult, and lead to duplication of effort in systems development, programming, and maintenance of company data files.

The COPICS framework is based on the relationship among the various portions of the system – that is, on "system integration". No company will attempt to implement at one time all of COPICS, but will attack a portion at a time. This involves defining the interfaces between application areas. Interfaces are essentially fixed-format segments of information that are passed between applications to initiate action. As long as these interfaces are adequately defined and held constant, system development and improvement can take place in small, manageable increments without disrupting existing applications.

The concept of integration also recognizes that a business decision is not made in a vacuum. A decision in one area can quickly and seriously affect conditions in others. Therefore, the information created, collected, and stored by one application area, say purchasing, must be made available to others who need it.

Development of a system based on COPICS minimizes the cost of system integration by using a common target. This avoids the need for major changes in systems defined previously and prevents costly functional overlap. It also leads to more profitable system development, because management can assign priority to those sections of COPICS that deal with the major problems of the company, and defer commitment to less significant projects.

Commitment to a comprehensive framework adaptable to many manufacturing situations offers special benefits for integrated but geographically diverse manufacturing operations. It means that the same basic system, with minor modifications to allow for specific local problems, can be installed at all plant locations. This not only reduces system development and installation costs, but also:

- Allows a common base for effective management evaluation
- Increases the effectiveness of the central organization in coordinating the activities of the interconnected plants
- Simplifies the transfer of manufacturing responsibility for specific products from one plant to another
- Facilitates promotion and transfer of people between plants, since similar systems will be used in all plants
- Allows easier startup of new plants, because a new plant can use another plant's system
- Avoids duplicate creation of common data

Depth of application definition

There is a similarity of problems and solutions among manufacturing companies. This similarity exists despite the wide diversity in products and manufacturing techniques. The following chapters do not give all of the possible alternative computer-based solutions to the manufacturing problems presented. They do, however, show a feasible solution that can be used by most manufacturing companies.

Neither do the following chapters address all the problems that a company will face when installing a new application, nor are they intended to be an installation guide. Because of the wide variety of present systems, the problems of conversion from these systems to COPICS are not discussed in detail. However, a brief discussion of conversion considerations is presented in *System Requirements.*

Application Areas

This section of the *Management Overview* highlights the major problems, objectives, and functions of the various COPICS application areas; detailed discussions appear in the respective chapters. The major justifications for installing the system are addressed following these application areas.

Engineering and Production Data Control

ENGINEERING AND PRODUCTION DATA CONTROL addresses the creation, organization, and maintenance of the basic engineering data used by the other sections of the system. This data, which is normally generated by design engineers, manufacturing engineers, and industrial engineers, consists of:

- *Bills of material,* describing what goes into a product or assembly
- *Manufacturing routings,* indicating the sequence of operations required to make the component or assembly
- *Manufacturing facilities data,* describing the machines, work centers, and tooling used in the production process

Additional data, such as engineering change data, engineering drawing data, and product history data, is also maintained by the system (Figure 14).

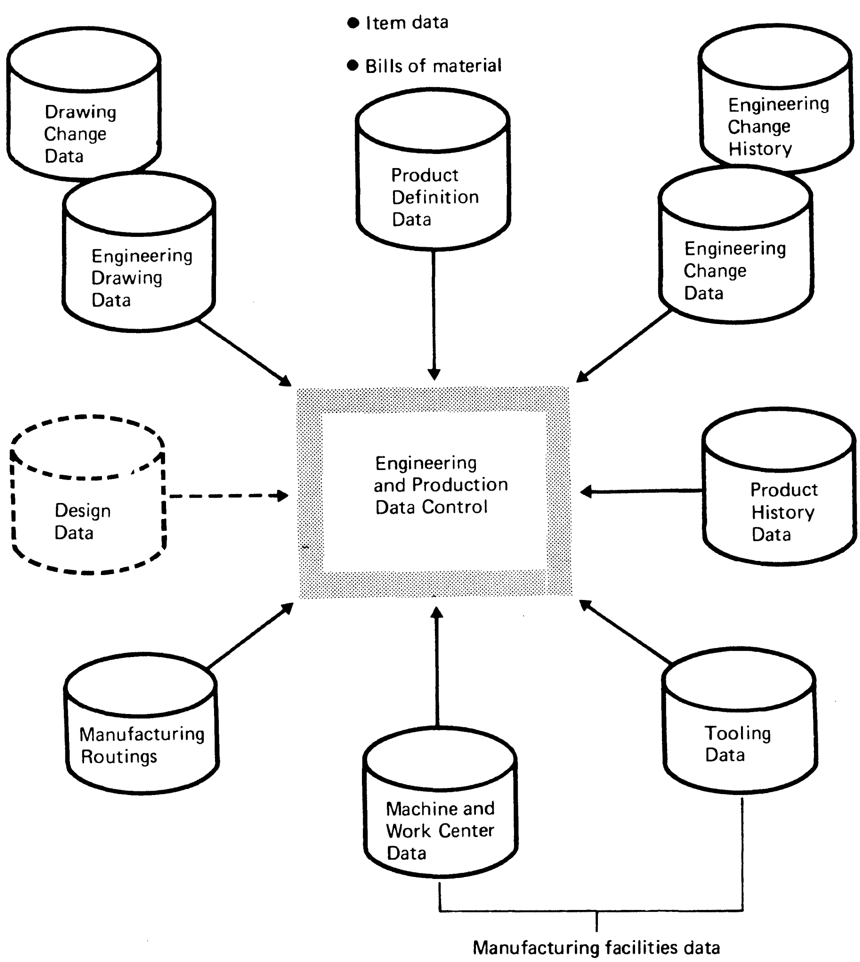


Figure 14. Information used and maintained by ENGINEERING AND PRODUCTION DATA CONTROL

Engineering data is subject to a large number of changes. However, the various departments that have to maintain the data do not always make the changes in the same way or at the same time. Thus the bill of material that may be maintained in Cost Accounting is usually not the same as that maintained in Engineering or Production Control. This means that decisions are made in different areas of the business that could affect the price, profitability, serviceability, and performance of the product, based on records that do not agree.

objectives

The major objective of ENGINEERING AND PRODUCTION DATA CONTROL is to organize and maintain these records in one central location accessible to all areas of the business. This "one set of books", or *data base,* eliminates costly duplication of records and ensures that all departments base decisions on the same data; the product is produced the way it was designed and costed the way it was produced.

system functions

Figure 15 outlines the basic functions discussed in *Engineering and Production Data Control.* Some of the highlights include:

- Coordinating the acquisition of all data needed to describe new items. Action Files requesting new data are maintained for each department responsible for supplying data.
- Creating new bills of material through the use of similar existing bills, thus reducing development engineering time and cost.
- Structuring bills of material so that all engineering departments can share the same data. Changes to the basic bill of material reflecting product variations, service assemblies, or production techniques are made in such a way that the total amount of data stored is minimized.
- Controlling engineering changes and determining in advance the probable cost effect of a pending engineering change. This allows the engineer to alter the change effectivity basis in order to reduce costs, or helps him justify proposed product or process changes.
- Tracing the location and status of new and revised engineering drawings and coordinating the physical issuing of blueprints.
- Creating and maintaining documents such as technical manuals and parts catalogs.
- Applying to repetitive design problems such techniques as Automated Design Engineering and Automated Manufacturing Planning, which can reduce the design cycle from weeks to hours. The resulting high-quality design becomes output to the system in the form of bills of material and manufacturing routings.
- Applying engineering information retrieval capabilities which, assisted by standardization techniques, allow the design engineer to quickly locate existing parts for new designs. This reduces duplication of parts and encourages standardization.

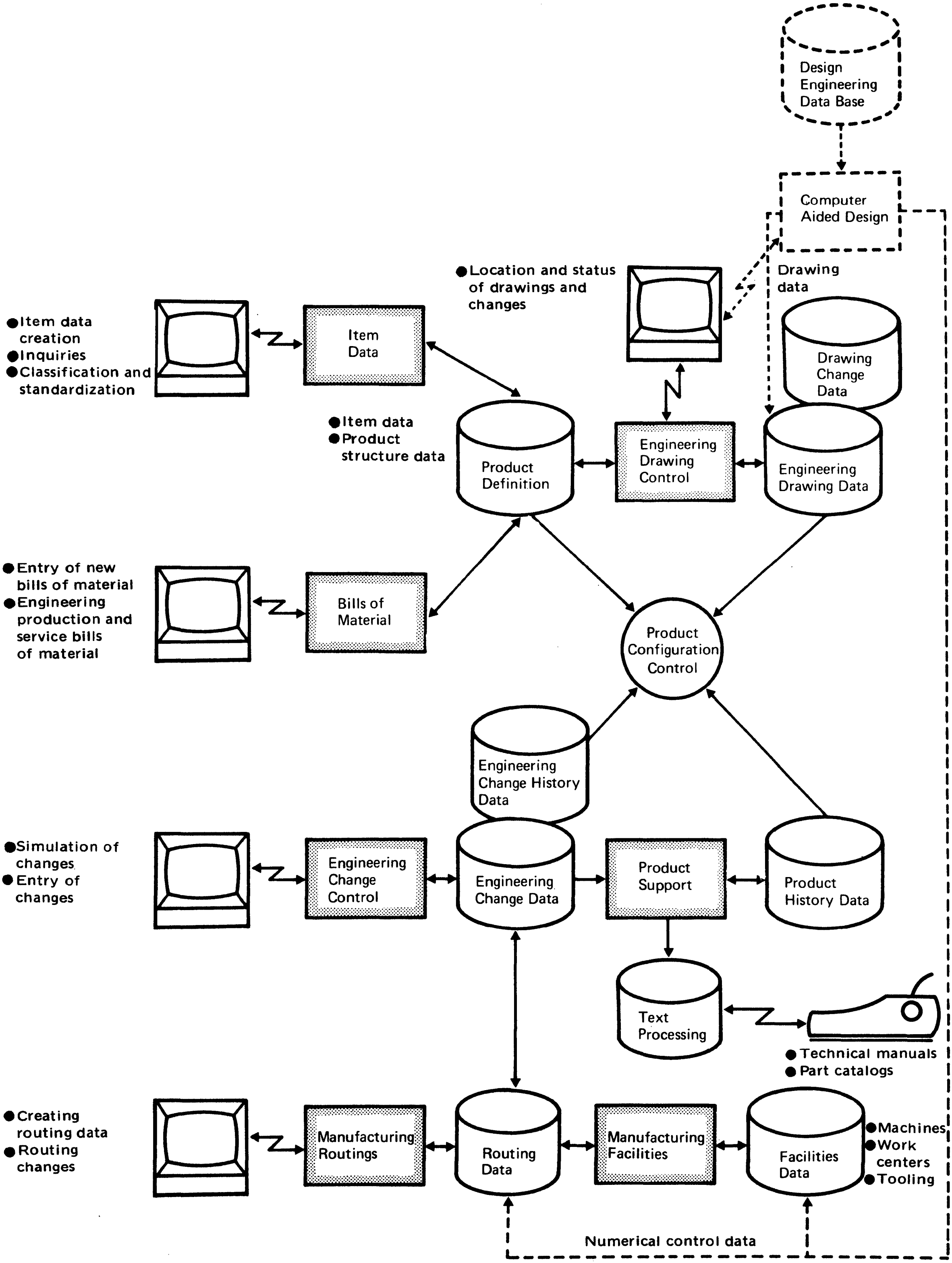


Figure 15. Basic functions of ENGINEERING AND PRODUCTION DATA CONTROL

Customer Order Servicing

CUSTOMER ORDER SERVICING is the application area involved with handling customer orders, quotation requests, and inquiries. The ability to do this rapidly and accurately is indispensable because companies are judged not only by the performance, quality, and price of their product, but also on how well they handle the customer's order.

The system described does not cover applications such as sales analysis or accounts receivable, although it provides the data required by these applications. It does cover the servicing of the customer's order from receipt of the quotation request and/or the entry of the order, to shipment of the finished product.

Other planning and control sections of COPICS provide accurate, detailed status information (such as probable shipping date) that makes improved customer service possible.

objectives

The objective of CUSTOMER ORDER SERVICING is to ensure rapid, accurate entry of quotations and orders into a control system that traces the progress of the order, thereby helping to ensure on-time shipment and improved response to customer inquiry.

Faster quotation and order entry is achieved by the use of terminals to enter order information. Figure 16 shows one approach to the use of terminals for order entry. This approach reduces the amount of data that must be entered and saves most of the time normally spent correcting entry errors.

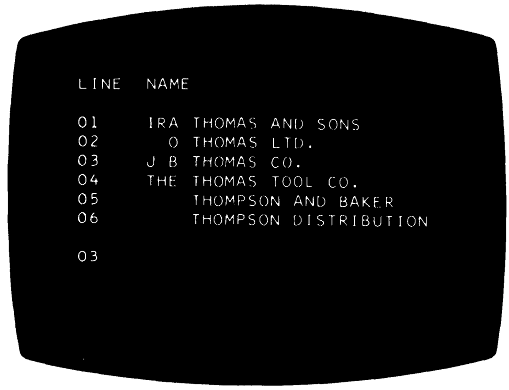
Accuracy of order entry is improved because the system guides the clerk through all order entry phases, thus ensuring that all data is entered. The system also audits the entered data and indicates errors. This reduces order delays and shipment errors that cause customer dissatisfaction.

system functions

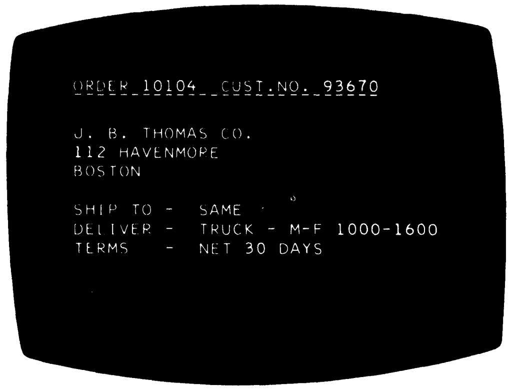
As Figure 17 indicates, CUSTOMER ORDER SERVICING relates to almost all other functional areas. Its functions are:

- *Order analysis and entry*, which identifies the customer and the products required, prices the product and creates order control records. An automated credit check is performed at this time.
- *Availability checking,* which determines whether the requested delivery date can be met, and, if not, the best date that can be quoted. Immediate allocation ensures that the same inventory is not promised to different customers.
- *Order control and shipment,* which monitors the unshipped order through design, production activity, and packing and shipping.

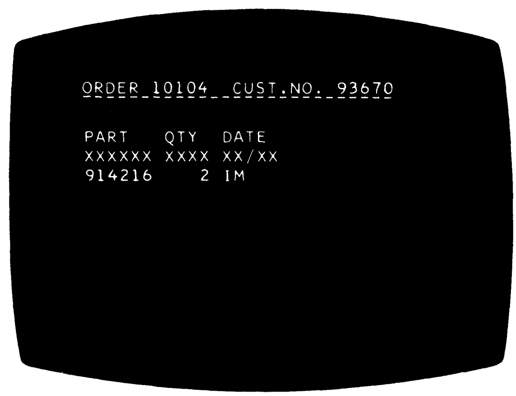
To enter order from J.B. Thomas Co. operator keys in "THOM" and selects correct customer from displayed customer list.



The system assigns an order number and displays the customer record which contains the customer number, the billing and delivery address, the standard delivery and order instructions held in the customer record.



Operator enters item number, quantity, and required delivery for first line of order. "IM" is code for immediate delivery.



Item description is displayed with earliest availability date. Data is checked against order. Order control totals are displayed.

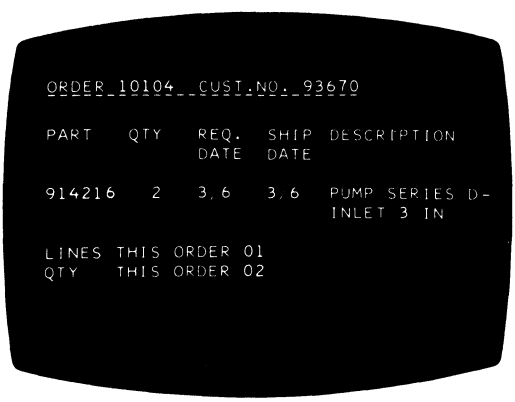
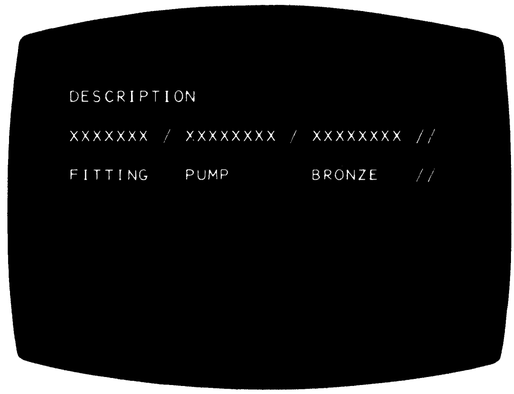
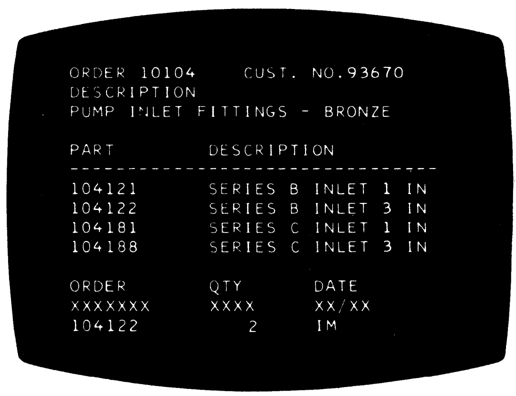


Figure 16. One example of how terminals can be used to enter customer order information (sheet 1 of 2)

The second line of the order quotes a description without an item number. Operator begins catalog search by entering description.



The section of the catalog requested is displayed. The operator selects correct fitting and enters quantity and date.



As before the system displays item number, description and earliest availability date, and order control totals.

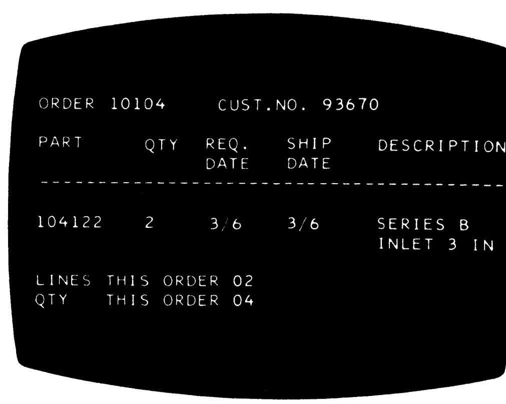


Figure 16. One example of how terminals can be used to enter customer order information (sheet 2 of 2)

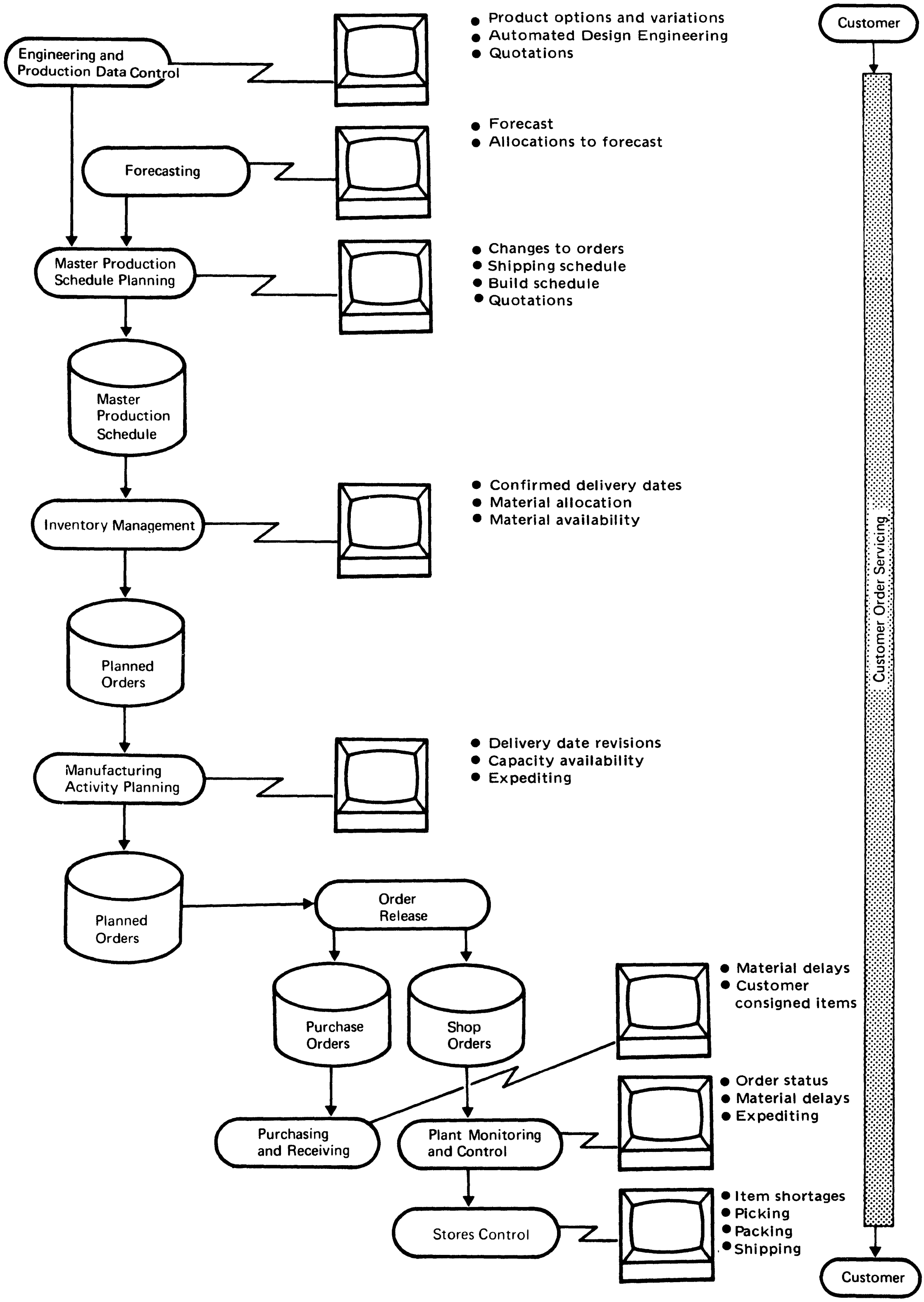


Figure 17. CUSTOMER ORDER SERVICING relates to almost all other functional areas.

- *Order information,* which is used not only for answering customer inquiries but also for evaluating the order backlog at each phase of order handling and the average amount of time an order spends in each phase. Excessive delays are flagged in Action Files.

The system also monitors the status of open quotations and indicates when follow-up or cancellation notices should be issued.

Where extensive design must be performed before all data can be entered, the system monitors and controls the phased entry of the necessary information.

Estimates of manpower load for the shipping department are prepared. Transport load planning, which is aimed at reducing shipping costs, is also a part of this application area.

Forecasting

All manufacturing companies forecast, and most managers forecast, even though the act of forecasting may not always represent a formal effort. The purpose of FORECASTING is to apply mathematical techniques to improve accuracy in this area. One of the most important manufacturing areas in which forecasting is used is development of the *master production schedule,* which specifies planned production for future time periods.

The use of forecasting techniques in manufacturing is not limited to finished products; other uses are indicated in Figure 18.

objectives

Despite the progress in forecasting techniques, the fact remains that there is no infallible way to predict the future. The object of the system, however, is to improve the accuracy of current forecasts and, more important, to predict how accurate the new forecasts will be. Measurement of forecast accuracy increases the effectiveness of planning decisions, since many business problems are related to errors in forecasting.

The economic impact of a grossly inaccurate forecast can be significant. If resource allocation is based on a demand forecast that is consistently too high, inventories of finished goods will increase and the productive capacity acquired to meet the load will not be needed.

If the forecast is consistently too low and resources are not sufficient to meet demand, the resulting delays may cause customers to change to other suppliers. Also, production facilities will be severely overloaded, resulting in increased expediting costs and overtime expenses.

Demand on Inventories	
Forecast	Not Forecast
End products Service parts End product variants Maintenance parts Indirect supplies Disposable tools	Component parts Jigs and fixtures Gauges Production equipment use

Management Performance Standards	
Forecast	Not Forecast
Labor efficiency Scrap factors Tool wear Rework load Machine downtime	Standard product cost Work center load Cash requirements

Figure 18. FORECASTING can be used in a large number of areas in manufacturing

The output of forecasting is a projection of what will happen in the future, that is, an estimate of the demand quantity for some future time period. When actual demand becomes known, it can be compared with the forecast. The difference between the forecast and actual demand is called forecast error. The anticipation of forecast error will allow realistic safety stock to be planned. This in turn will allow the plant to absorb normal fluctuations in business volume without expensive expediting and overtime.

Improved forecasting techniques reduce forecast error and thus allow a reduction in the business buffers maintained to absorb forecast error. This means less inventory, less work-in-process, fewer stockouts, etc. The techniques allow management to balance the requirement for a level production schedule with the requirement for a forecast responsive to customer requirements.

system functions

The basic functions of FORECASTING, as summarized in Figure 19, include:

- Data conditioning, which points out such historical data problems as missing data or extremely high or low points of demand. It employs correction procedures through terminal display of data.
- Using forecast model selection techniques for finding the best way to represent consistent patterns of demand, thereby improving forecast accuracy.
- Projecting future demand by time period for as many periods as required by the planning system using the forecast.

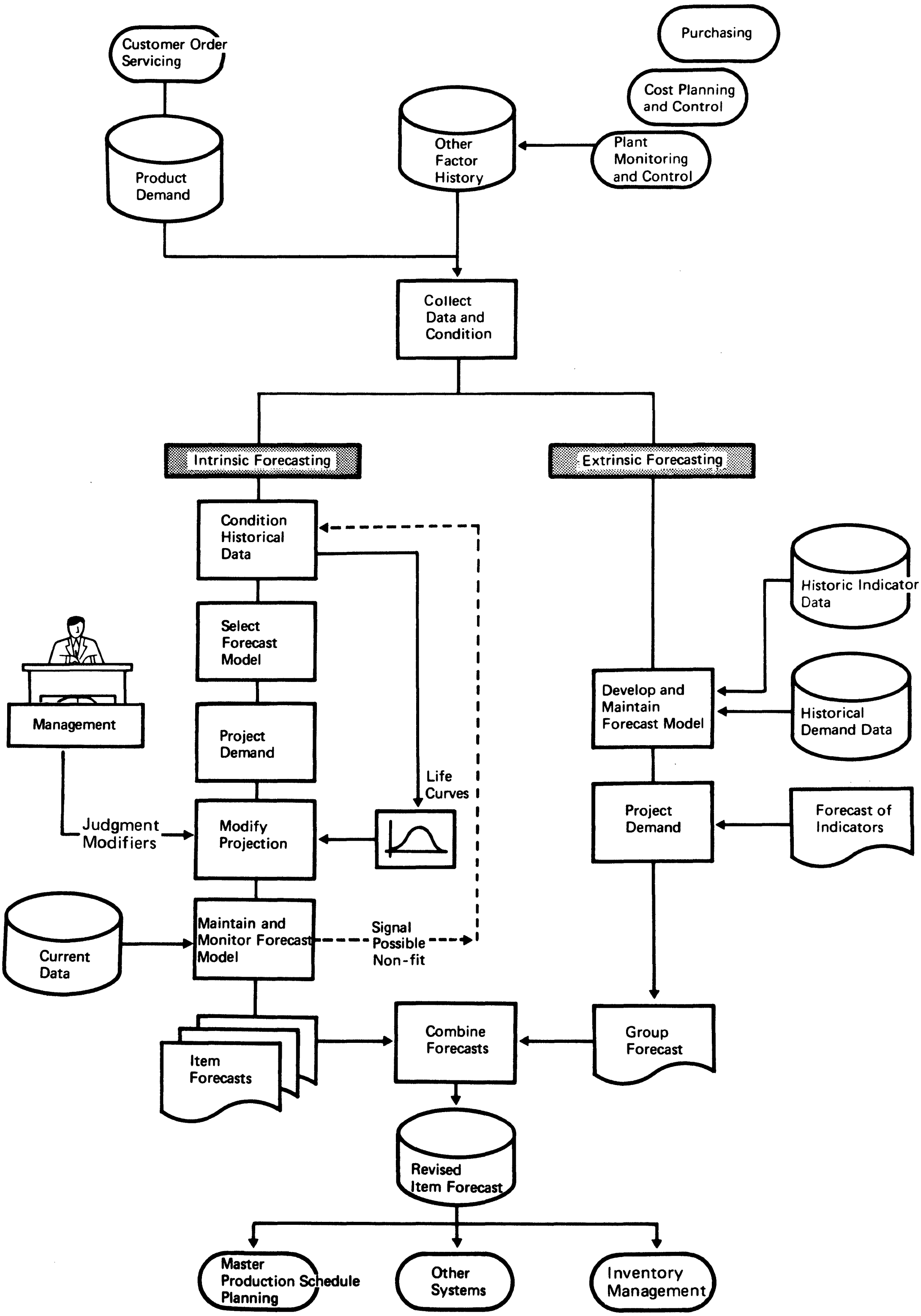


Figure 19. Basic functions addressed in FORECASTING

- Applying life curves that modify long-range projections according to the history of similar items. This improves the accuracy of long-range forecasts.
- Applying judgment factors that allow management to correct for the effect of one-time occurrences known in advance. These would include sales contests, new product announcements, market expansion, pricing changes, strikes, actions by competitors, abnormal economic conditions, etc.
- Monitoring to ensure that the current forecast models are still applicable and to minimize manual intervention.
- Developing forecast models based on economic and other business factors external to the business.
- Adjusting individual item forecasts to be consistent with forecasts of the item's group – for example, forecast of optional features should agree with the forecast of the product on which they are used.

Master Production Schedule Planning

A *master production schedule* is a statement of future product requirements specified by date and quantity (Figure 20). It reflects management inventory policy as well as customer demand.

MASTER PRODUCTION SCHEDULE PAGE 25

PRODUCT: ELECTRIC MOTOR 927

MONTH	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	
QUANTITY	700	750	800	850	900	900	900	900	

Figure 20. Example of a master production schedule

Every master production schedule is in a state of change. There may be little relationship between today's requirements and those predicted a year ago. The schedule can be thought of as a moving scroll (Figure 21). The further into the future a projection is made, the more uncertain the estimate becomes. As time passes, requirements become better known and when they enter the material requirements planning horizon they should be reasonably firm. However, urgent customer orders may be added to the schedule, within the normal manufacturing lead time, at very short notice. The schedule can be considered static only when it becomes history.

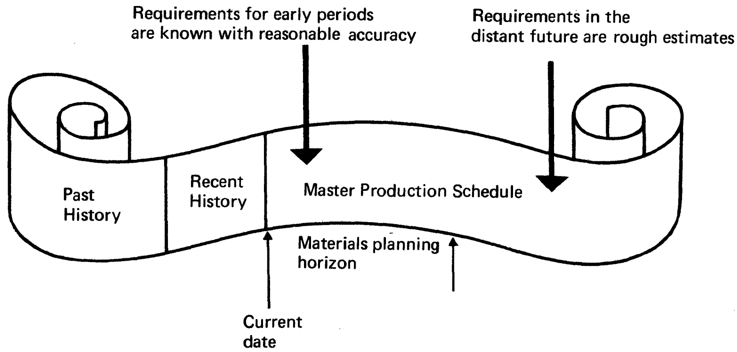


Figure 21. The master production schedule can be thought of as a moving scroll which constantly changes

objectives

The objectives of MASTER PRODUCTION SCHEDULE PLANNING are:

- To provide input to INVENTORY MANAGEMENT in order to determine short-term production requirements for all lower-level items, such as subassemblies, components, and raw materials
- To estimate the long-term demand on the company's resources such as production capacity, engineering, and cash requirements

To determine lower-level requirements, finished product requirements are "exploded" into a series of planned purchase orders and shop orders that indicate the date of all future order releases. This is performed in INVENTORY MANAGEMENT over the materials planning horizon.

To provide long-term estimates of the resources required, the master production schedule must normally be extended to cover a long period, perhaps several years. Long-range planning is essential because resources such as new production facilities may take months or years to acquire.

The system determines a summarized estimate of all production resources required to meet a specific master production schedule. This assists the schedule planner in making adjustments to the schedule and to the planned resource levels in order to obtain a realistic schedule. Unless the schedule is realistic, the detailed planning to follow will be ineffective.

Industries with seasonal demand usually need to level production. The system can be directed to average the demand and thus stabilize the production rate. The inventory level resulting from stabilizing production is also estimated.

Figure 22 outlines the basic steps of MASTER PRODUCTION SCHEDULE PLANNING, which are:

system functions

- A revised forecast, a customer order, or a change to a current order creates a *net change* to the current master production schedule.
- The system maintains in a product and resource summary file the load imposed on production resources by each of the types of finished product. Each is called a *product load profile.*
- The net changes (plus or minus) to the schedule, plus the product load profiles, are used to calculate the net change to production facilities load. The planner can quickly recognize if the new schedule exceeds preestablished load limits.
- Alterations to the plan are simulated to test the load on facilities, and thus detect major overloads and underloads that would result from proposed schedule changes.
- Once it is determined that the modified schedule does not impose tasks that cannot be met, the net changes to the schedule are input to INVENTORY MANAGEMENT; this system then initiates the detailed plan to implement the change.

Inventory Management

In many manufacturing companies, management has little actual control over the level of inventory investment. Inventories typically tend to grow until some often arbitrary action is taken to reduce them. Investment in inventory is often not planned – it just happens.

From an investment standpoint, the ideal situation would be to carry little or no inventory. However, inventories are required for a variety of reasons. Many types of inventory are simply a function of operating a manufacturing business.

Inventories are of concern to management not merely from an investment (tied-up cash) point of view, but because inventory levels are directly related to customer delivery service, manufacturing lead times, several elements of overhead, and writeoff due to obsolescence.

INVENTORY MANAGEMENT is designed to serve as a comprehensive and highly effective tool, through which management can plan and truly control inventories at the level of finished goods, work-in-process, and raw materials.

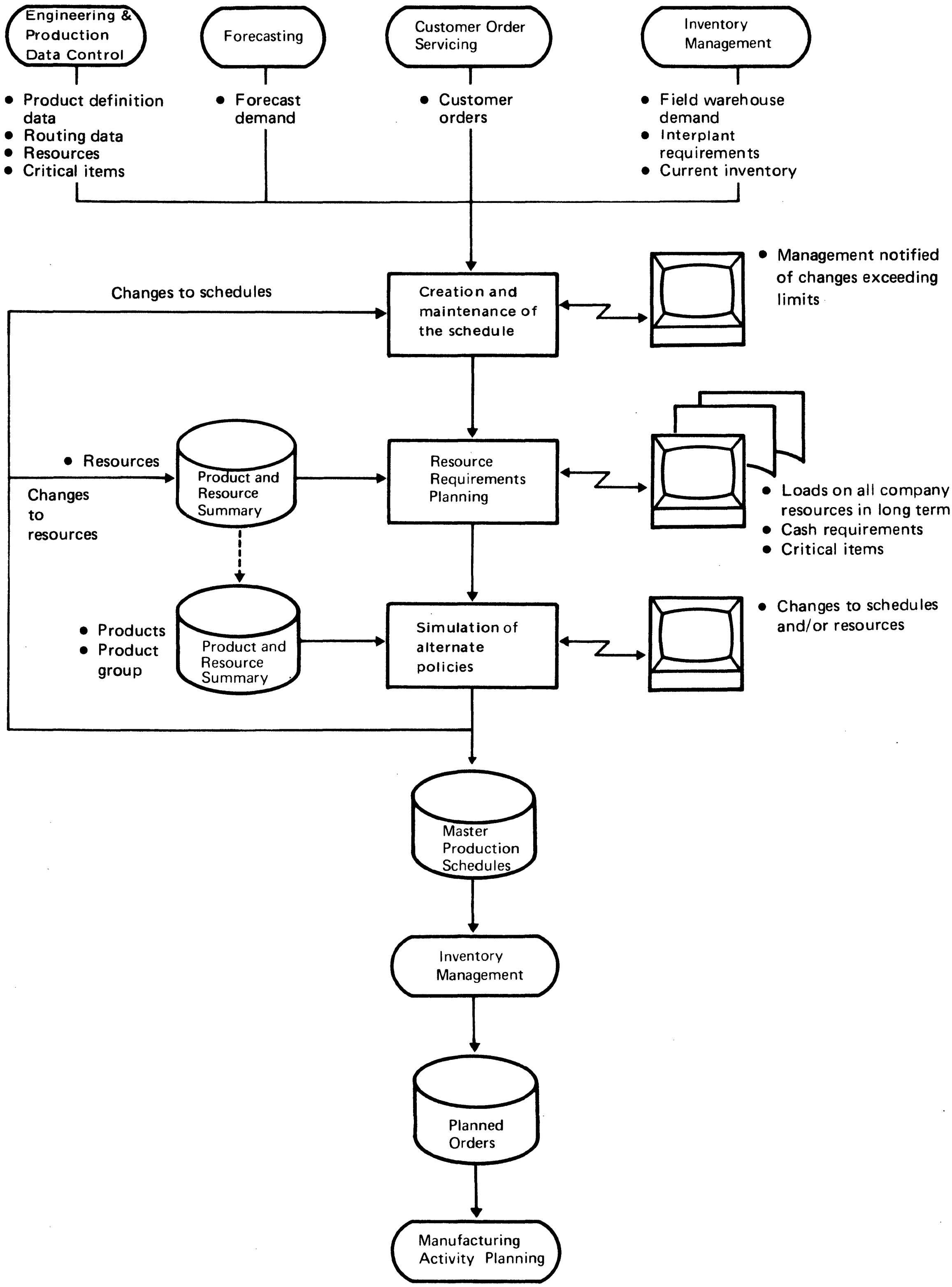


Figure 22. Basic steps of MASTER PRODUCTION SCHEDULE PLANNING

The techniques outlined help ensure that the following inventory management control objectives are met:

objectives

- Improved customer service, by reducing the number of shortages and late customer deliveries through improved timing of component part deliveries
- Reduced investment in all types of inventory, including maintenance parts and tools

In addition to these purely inventory-oriented objectives, INVENTORY MANAGEMENT is designed to provide, through its material requirements planning capability:

- A reliable basis for projecting production capacity requirements
- Continuous reevaluation of all released order due dates, which is prerequisite to maintaining valid priorities of work on the factory floor.

Order size and the size of safety stock buffers can be varied by management, and thus the level of inventory can also be varied, within a significant range. INVENTORY MANAGEMENT helps minimize inventory levels consistent with the stated management objectives of customer service level, order costs, and stability of production.

Changes in customer requirements, engineering changes, new product introductions, unforeseeable delays, excessive scrap, etc., require a system that can react and replan quickly, minimize shortages, and still maintain a minimum investment in inventory. INVENTORY MANAGEMENT provides such a system.

system functions

INVENTORY MANAGEMENT provides two major functions: INVENTORY ACCOUNTING and INVENTORY PLANNING AND CONTROL (see Figure 23).

INVENTORY ACCOUNTING applies to all types of inventory and deals with the sources of the most common transactions, how these transactions affect inventory status records, and how terminal entry of transactions and the system's auditing methods improve accuracy of reporting and ensure system integrity.

INVENTORY PLANNING AND CONTROL applies to all inventory items, irrespective of their source of demand. This includes end products, service parts, subassemblies, piece parts, and raw materials. It is made up of the following individual functions, incorporated into a single time-phased material requirements planning framework:

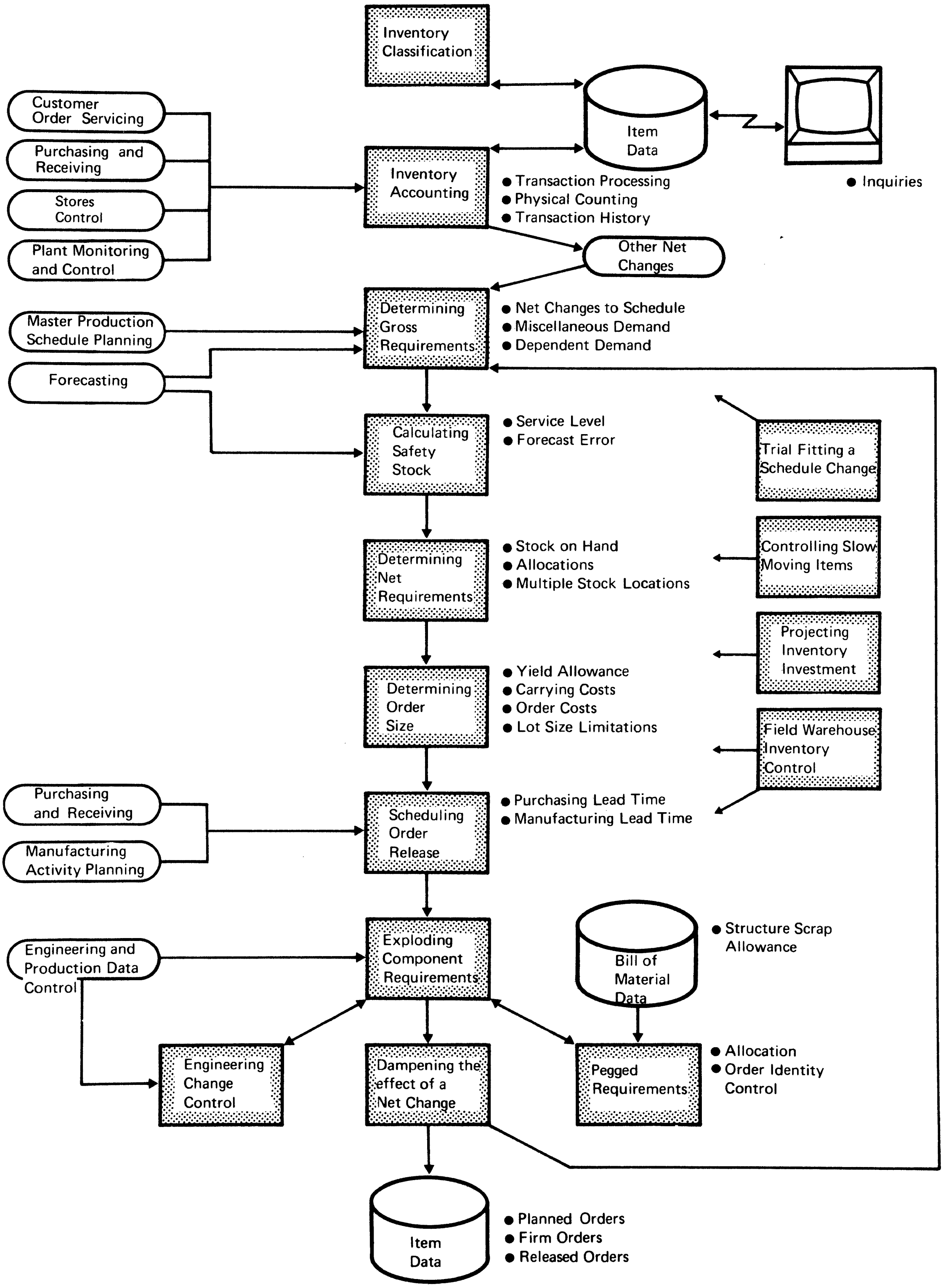


Figure 23. Basic functions of INVENTORY MANAGEMENT

- *Entry of gross requirements.* Material requirement sources are outlined, and the way end item gross requirements are entered into the system is described.
- *Determining net requirements.* On-hand inventory plus orders already released to the shop floor and suppliers are subtracted from end item gross requirements (Figure 24). The remaining *net requirements* are then covered by *planned orders.*
- *Calculating safety stock and safety lead time.* By use of a management-selected service level and the measure of forecast error, an inventory buffer is calculated. Safety stock is used primarily to absorb fluctuations in customer demand for finished products and service parts. Safety lead times, which represent forward adjustments in delivery dates, are applicable primarily to purchased items.
- *Determining order size.* To balance the costs of acquiring and carrying inventory, the system helps determine economical order quantities.
- *Scheduling order release.* The order is scheduled to cover remaining net requirements (Figure 25). The release date of the order is based on the normal manufacturing or purchasing lead time. Component requirements (components, subassemblies, raw materials) are normally required when the order for the "parent" item is released (Figure 26) and therefore must be scheduled to be available on that date.
- *Exploding component requirements.* Planned orders for assemblies are *exploded* to develop requirements for the assembly's components. Explosion involves multiplying the assembly order size by the required component quantity indicated in the bill of material.

Period	1	2	3	4	5	6	7
Gross	10	12	14	14	12	14	14
On Hand	16						
On Order		25					
Net	0	0	0	9	12	14	14

Figure 24. Determining net requirements

Period	1	2	3	4	5	6	7
Net Requirements	0	0	0	9	12	14	14
Planned Orders				25		25	

Figure 25. Planned orders cover net requirements

Special considerations in inventory planning and control, discussed in this chapter, address the following subjects:

- *Inventory classification.* This helps determine on which items stringent and accurate control procedures will have the greatest benefit.
- *Engineering change control.* The criteria for determining when engineering changes are to become effective are discussed.
- *Pegging component requirements.* Available and planned inventory is allocated by the system to requirements generated from various sources. *Pegging* is used for several reasons, including tracing the effect of a component delay on a customer order.

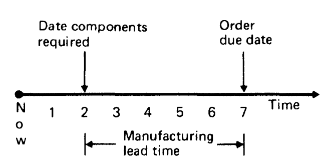


Figure 26. Component requirements are offset five periods from assembly order due date

- *Trial-fitting a proposed schedule change.* The ability of the system to replan rapidly can be used to predetermine the detailed effect of a proposed schedule change. The system highlights materials that must be expedited and the probable effect on other orders.
- *Projecting inventory investment.* As part of its planning function, the system calculates how much inventory is expected to be on hand in every time period. This can be used to plan cash requirements.
- *Material requirements planning for interrelated multiplant situations.* The ability to replan rapidly based on net changes to production schedules, together with high-speed data transmission between interrelated plants, opens up new approaches to materials planning for multiplant environments. The approach presented allows total manufacturing lead time to be significantly reduced, which in turn allows faster reaction to master production schedule changes.
- *Branch warehouse inventory control.* Special planning problems are considered when company-controlled branch warehouses are part of the finished product distribution network.

This chapter concludes with a discussion of principles that should govern the use of the system. Methods of dampening the effects of change are reviewed, as are the principal categories of system outputs, and their use.

Manufacturing Activity Planning

The problems addressed in MANUFACTURING ACTIVITY PLANNING are common to many manufacturing companies. These problems are uneven factory workloads, long manufacturing lead times, and, consequently, excessive work-in-process inventory and high expediting expenses. Basically, these problems stem from difficulty in maintaining shop order priorities, bottleneck conditions due to inadequate capacity planning, and component shortages. MANUFACTURING ACTIVITY PLANNING addresses these functions and defines the appropriate solutions.

In most manufacturing companies, shop orders spend much more time (often ten times as much) waiting at work centers (waiting in queue) than being processed. A queue at a work center can be compared to water in a tank (Figure 27). Output of the work center is limited by its work capacity; output from the tank by the dimensions of the outlet. There are three possible situations:

- If input equals output, the work queue (water level) stays constant.
- If input exceeds output, the work queue increases.
- If output exceeds input, the work queue decreases.

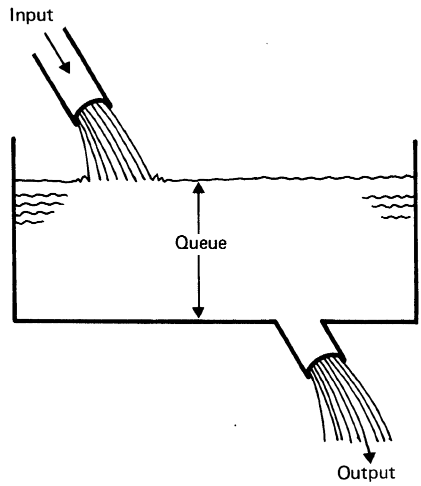


Figure 27. If the output rate is the same as the input rate, the queue size stays the same

A queue can be decreased only by increasing the output or decreasing the input. If this is done for too long a period of time, however, the queue eventually disappears entirely and idle time may result. On the other hand, if the input to a work center consistently exceeds the output, the queue grows steadily. Once an excessive queue has developed, it remains excessive even if perfect balance is later achieved between work input and output. If work-in-process is to be adequately controlled, any unnecessary queues or buffers of work must be detected and removed, and work input and output must be kept in balance.

objectives

The component and subassembly production schedules established by INVENTORY MANAGEMENT to meet delivery dates govern all future manufacturing activity. A major objective of MANUFACTURING ACTIVITY PLANNING is to make these schedules a reality by helping to plan the capacity level (machines and manpower) required to meet them.

Another objective is the reduction of the work-in-process inventory. This type of inventory is costly – not only in terms of investment, but also in terms of increased shop congestion, long lead times, materials handling costs, and floor space requirements. MANUFACTURING ACTIVITY PLANNING helps to control the level of work-in-process by planning capacity, regulating the rate at which orders are released to the shop floor, and sequencing their operations.

MANUFACTURING ACTIVITY PLANNING is also designed to help reduce and control manufacturing lead times (which are usually longer than really necessary). These lead times are a *function* of the work-in-process inventory level. With less work-in-process, the time a job must wait in queue for a machine is reduced and total lead time is shortened.

MANUFACTURING ACTIVITY PLANNING is also concerned with minimizing idle machine time, a major factor behind the existence of job queues. Neither foremen nor workers welcome idle time, and the knowledge that the work queue is shrinking can cause a reduction in the work rate until the "normal" situation has been restored. Queues can be reduced more easily if foremen become convinced that idle time will rarely occur. This application area minimizes idle time by scheduling the sequence of work to keep men and machines running at planned capacity. It keeps foremen fully aware of what is now in their job queue and what work will arrive in the near future.

system functions

Efficient planning and balancing of capacity are achieved in COPICS in several manageable stages. Capacity is never static and workloads are constantly changing, so detailed planning too far out into the future is avoided.

The initial capacity planning is performed in MASTER PRODUCTION SCHEDULE PLANNING, which attempts to level the gross loads that the schedule represents, and to make sure that the master production schedule is feasible in view of planned capacities. The time span covered in this type of planning may be up to several years. Capacity decisions involve plant, equipment, and skilled manpower.

INVENTORY MANAGEMENT converts the master production schedule into detailed production schedules for lower-level components. These detailed schedules become input for MANUFACTURING ACTIVITY PLANNING, which attacks the problem of balancing capacity in three stages (Figure 28):

- CAPACITY REQUIREMENTS PLANNING. This stage plans the output side of the balancing problem by helping to establish a period-by-period capacity capable of covering production requirements. Balancing the capacity starts with determining detailed capacity requirements (workloads). The planner then plans capacity adjustments to overloaded or underloaded work centers.

  Analysis of the load by means of a terminal (Figure 29) enables him to make recommendations such as the need for hiring production workers, subcontracting or performing work for other plants, planning extra shifts, or planning overtime work.

- ORDER RELEASE PLANNING. This second stage may adjust the date on which the planned order is to be released to the shop floor. Together with OPERATION SEQUENCING, it levels the planned load on each machine center.

  It also determines which orders should be released early to prevent idle time. These decisions are based on calculated order priorities. At this stage the system also estimates the completion time for each shop order and customer order.

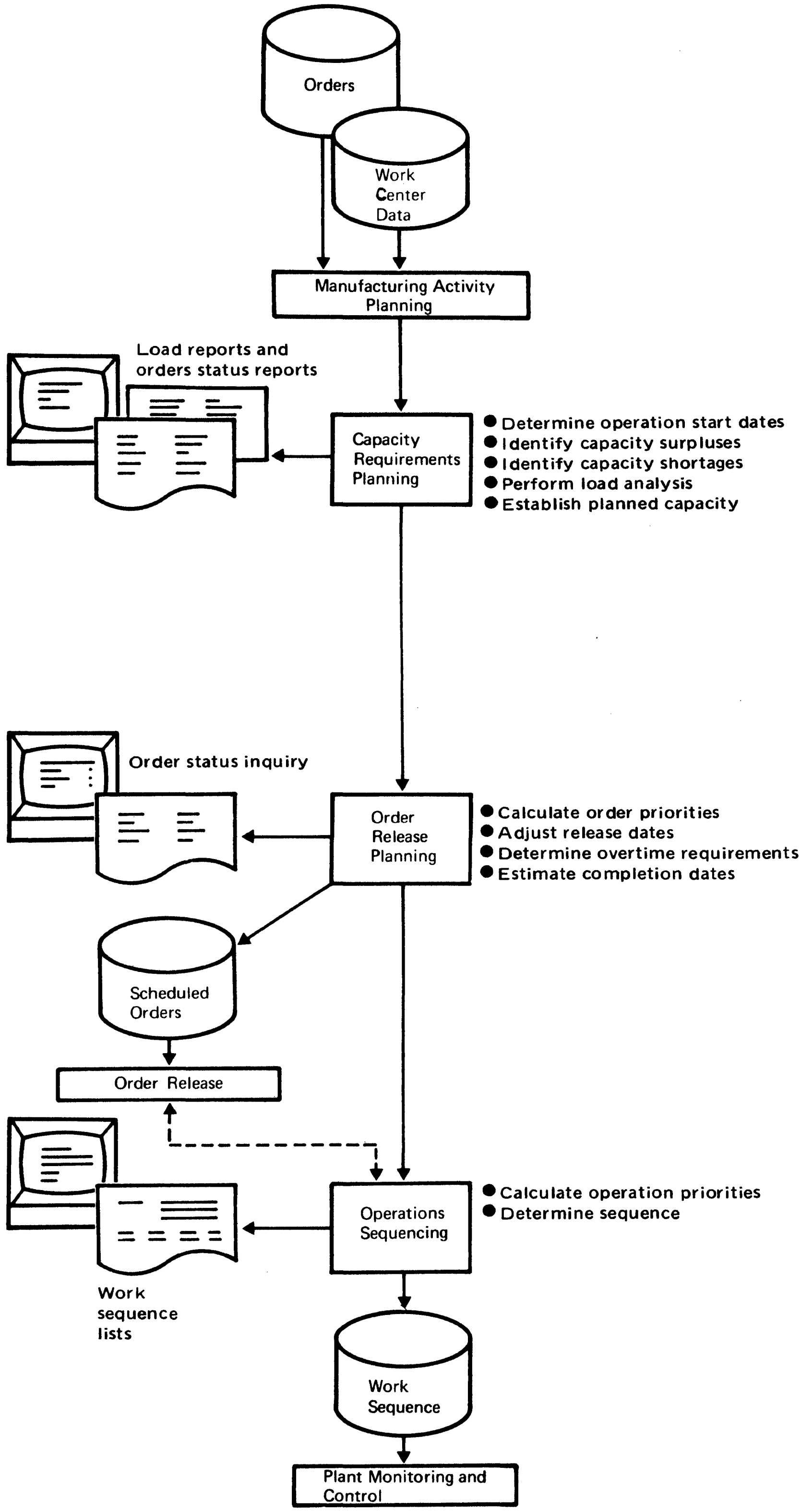


Figure 28. MANUFACTURING ACTIVITY PLANNING is done in three stages

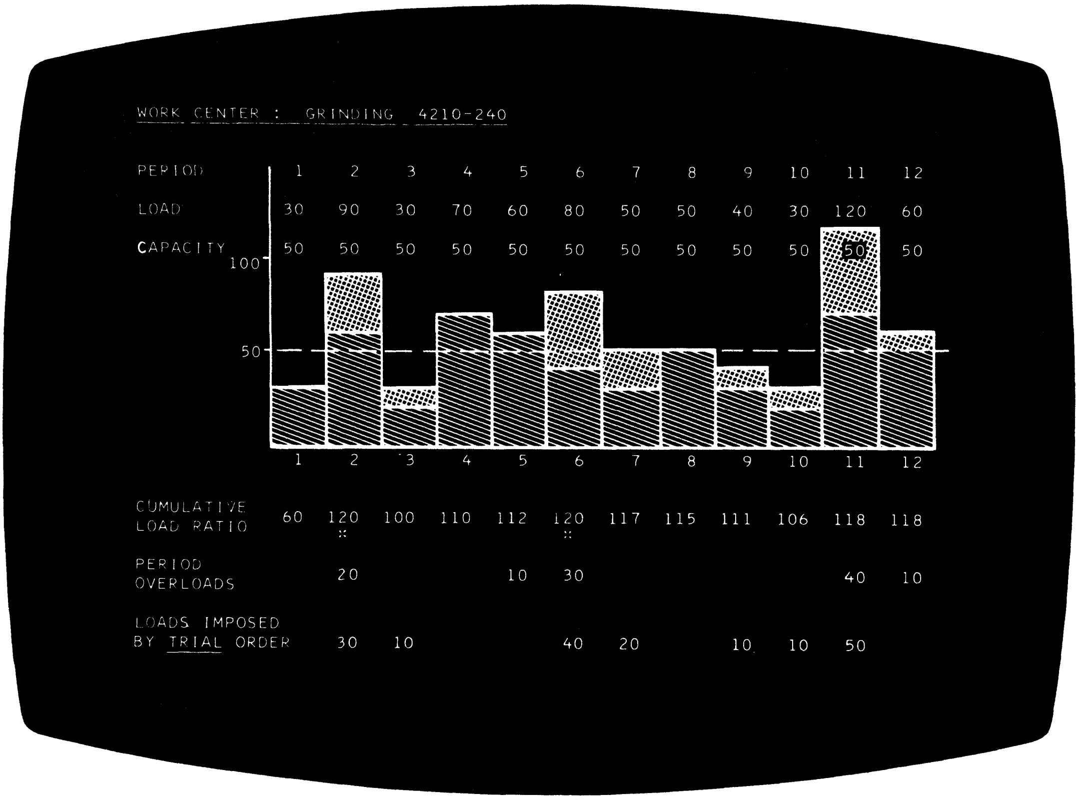


Figure 29. Example of the type of load report that can be displayed to analyze critical load situations

- OPERATION SEQUENCING. The third stage of MANUFACTURING ACTIVITY PLANNING produces a work sequence list, which is the basis for assigning work to machines and operators. The sequence reflects the decisions made in the previous planning phases and takes into account the latest conditions on the shop floor. By simulating the minute-by-minute situation in the factory, OPERATION SEQUENCING attempts to keep machines from running out of work or becoming bottlenecks.

Order Release

ORDER RELEASE is concerned with the connection between the planning and execution phases of the system. The primary output of the planning phase is *planned orders,* which indicate a release date and quantity. Up to this point, the planned order usually represents no commitment and can therefore be easily altered. The function of ORDER RELEASE is to change the status of the order from "planned" to "released". Shortly after release, either a purchase order will be placed or operations will be started on manufactured components and subassemblies. It may be difficult and expensive to alter an order after its release.

Unless each order is committed for production or purchase on its planned release date, some of the benefits of planning will be lost. ORDER RELEASE is intended to ensure that each order is released on the appropriate date. objectives

INVENTORY MANAGEMENT schedules components and materials required for shop orders so that they are available at order release time. ORDER RELEASE verifies that the material is physically available and maintains a record of allocated components. The system can be instructed to hold up release until all components are available. This eliminates the need for physical staging to determine what items are short.

Production cannot start until components, tools, and manufacturing drawings have been issued. ORDER RELEASE authorizes their issue by generating the necessary requisitions.

Requests for components are in the form of material requisitions, which instruct stores personnel to collect and issue the necessary items. ORDER RELEASE maintains a Requisition Action File in a priority sequence which helps ensure that important shop orders are serviced first.

Each shop order is accompanied by a manufacturing routing and a shop order identification card. ORDER RELEASE initiates these documents.

system functions

The basic functions of ORDER RELEASE, as shown in Figure 30, are as follows:

- The planned order release dates established by the previous planning systems are periodically reviewed. On the order release date, the detailed functions performed by the release system depend on whether it is a shop or purchase order.
- For shop orders, the physical availability of materials and tools is checked. This prevents the release of orders that cannot actually be started.
- If material and tools are available, components not previously allocated in detail are now allocated. This ensures that components in short supply are issued to high-priority orders.
- Material and tool requisitions are generated.
- Shop order documentation is prepared and Action File notices for locations supplying additional documentation are generated.
- For purchase orders, requisitions are placed on the Buyer's Action File.
- If the purchase order is for a subcontracted operation, material requisitions for the items supplied to the subcontractor are issued via the Stores Action File.

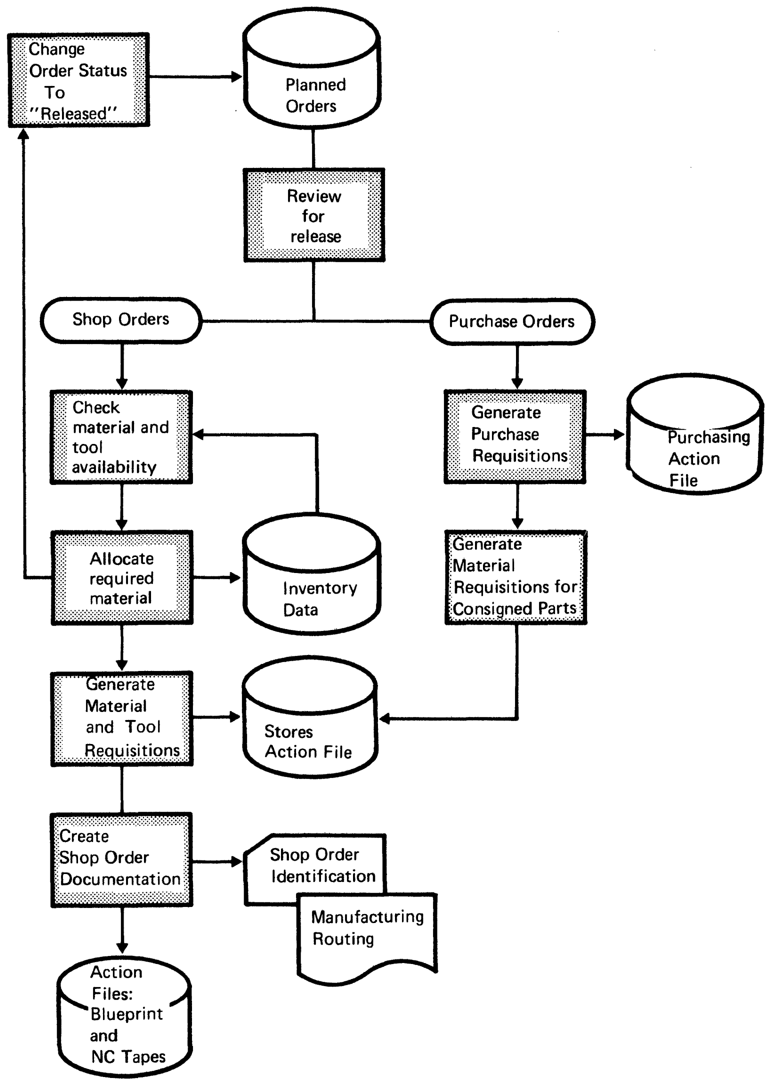


Figure 30. Basic functions of ORDER RELEASE

Plant Monitoring and Control

Many problems on the shop floor are caused by inadequate or late planning. Changes to production schedules, engineering changes, or changes to specific customer orders can mean that manpower must be shifted, or that shop documentation must be withdrawn or changed. Furthermore, "teardowns", "send-aheads", and "holdups" due to material shortages become excessive. Implementation of INVENTORY MANAGEMENT and MANUFACTURING ACTIVITY PLANNING reduces these problems. Even with good planning, however, unforeseen interruptions, such as machine breakdowns and excessive scrap, cause delays in the operations and additional waiting time at the work center. Each delay sets off a chain of further delays throughout the shop.

PLANT MONITORING AND CONTROL implements the production plan and serves to reduce the number of delays and waiting time by more effective monitoring and feedback of production and shop floor status data. This data may be obtained either through terminals located on the shop floor, or through direct connection of the computer to the machine tools. With this data readily available, the system minimizes delay by means of communication links to production support departments, such as Maintenance and Materials Handling. In addition, it can broadcast the effect of a delay to other affected departments, so that they have the option of shifting their attention to other orders.

objectives

The first objective of PLANT MONITORING AND CONTROL is to ensure that the production schedule is being met. Output by work center is measured. Shop order status information is updated as the order progresses through the plant, and out-of-line situations are highlighted via Action Files for prompt corrective action.

The second objective is to provide better coordination between production and the supporting activities. This can reduce the amount of time operators spend waiting or looking for materials, tools, materials handling equipment, and inspection. Since delays caused by interruptions are reduced, the work queues at each machine, maintained to absorb fluctuations in work arrival rates, can also be reduced. The overall effect is lower work-in-process inventory and a shorter manufacturing lead time.

Better coordination also results in more effective utilization of the support functions, such as maintenance, materials handling, and inspection (Figure 31), and enables the foreman to make better use of his time.

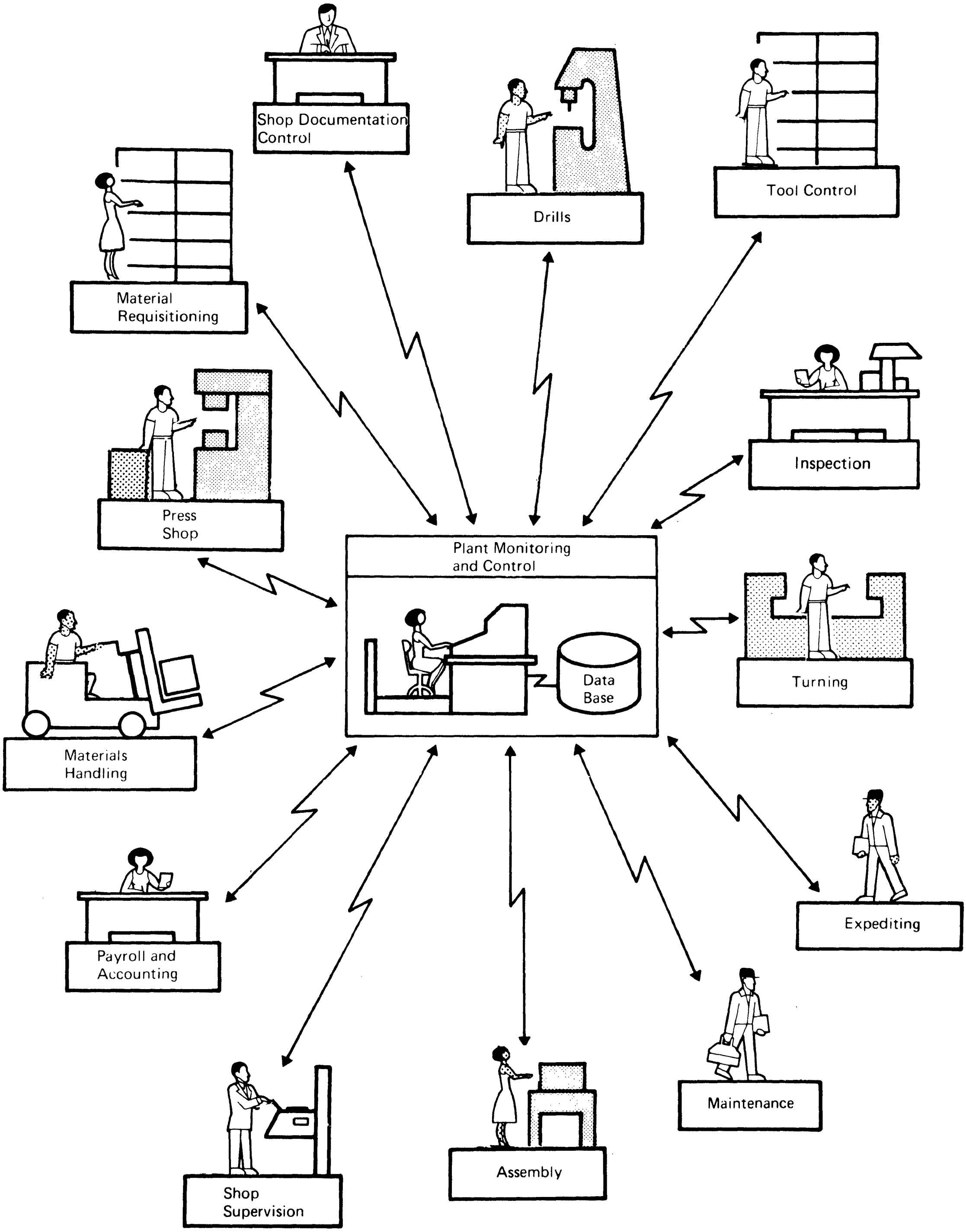


Figure 31. PLANT MONITORING AND CONTROL provides coordination of all activities related to the shop floor

The third objective of PLANT MONITORING AND CONTROL is to improve the efficiency and utilization of production, testing, and materials handling equipment through direct machine monitoring and control. These techniques allow for the continuous collection of such basic data as piece count and run time. In addition, control of the machine directly by the computer allows for such things as flexibility of test sequence based on test results, changing of cutting speeds as a result of varying metal hardness, the constant monitoring of machine performance against standard, and automatic tool change scheduling and analysis.

system functions

As Figure 32 shows, the basic functions of PLANT MONITORING AND CONTROL are:

- *Attendance reporting.* At start of shift, terminal entry of attendance information allows quick assessment of the ratio of planned to actual manpower for each department or critical work center.
- *Materials requisitioning.* The system coordinates delivery of material required at other than the first operation. This means that material required in later operations is not handled unnecessarily and that inventory on the factory floor is reduced.
- *Shop documentation control.* The need for floor changes to shop documentation is reduced because orders are released just before the first operation instead of days or weeks in advance. Required changes are incorporated quickly and easily through the use of terminals.
- *Job assignment.* The work sequence list prepared in MANUFACTURING ACTIVITY PLANNING takes into account the overall scheduling objectives of plant management. Displayed on a terminal, it suggests to the foreman the sequence in which jobs should be performed (Figure 33). As production activities take place, it is updated to reflect the latest status. The foreman utilizes it in assigning jobs. Having freedom in how he makes actual assignments, he uses his knowledge of individual worker skills, machine tolerances, etc., in making the assignment.
- *Job dispatching.* When reporting completion of a job, a worker immediately receives the assignment of his next job while still at the terminal. The system ensures that all required materials, tools, etc., have already been delivered to the machine or assembly area.
- *Manufacturing activity reporting.* The worker uses a simple terminal located at or near his work area to report completion of setup and any interruptions to normal production. The reporting of certain types of interruption, such as "material low" or "machine down for electrical repair", triggers requests for assistance from the foreman and the responsible support department. Activity reporting ends with the reporting of the completed job.

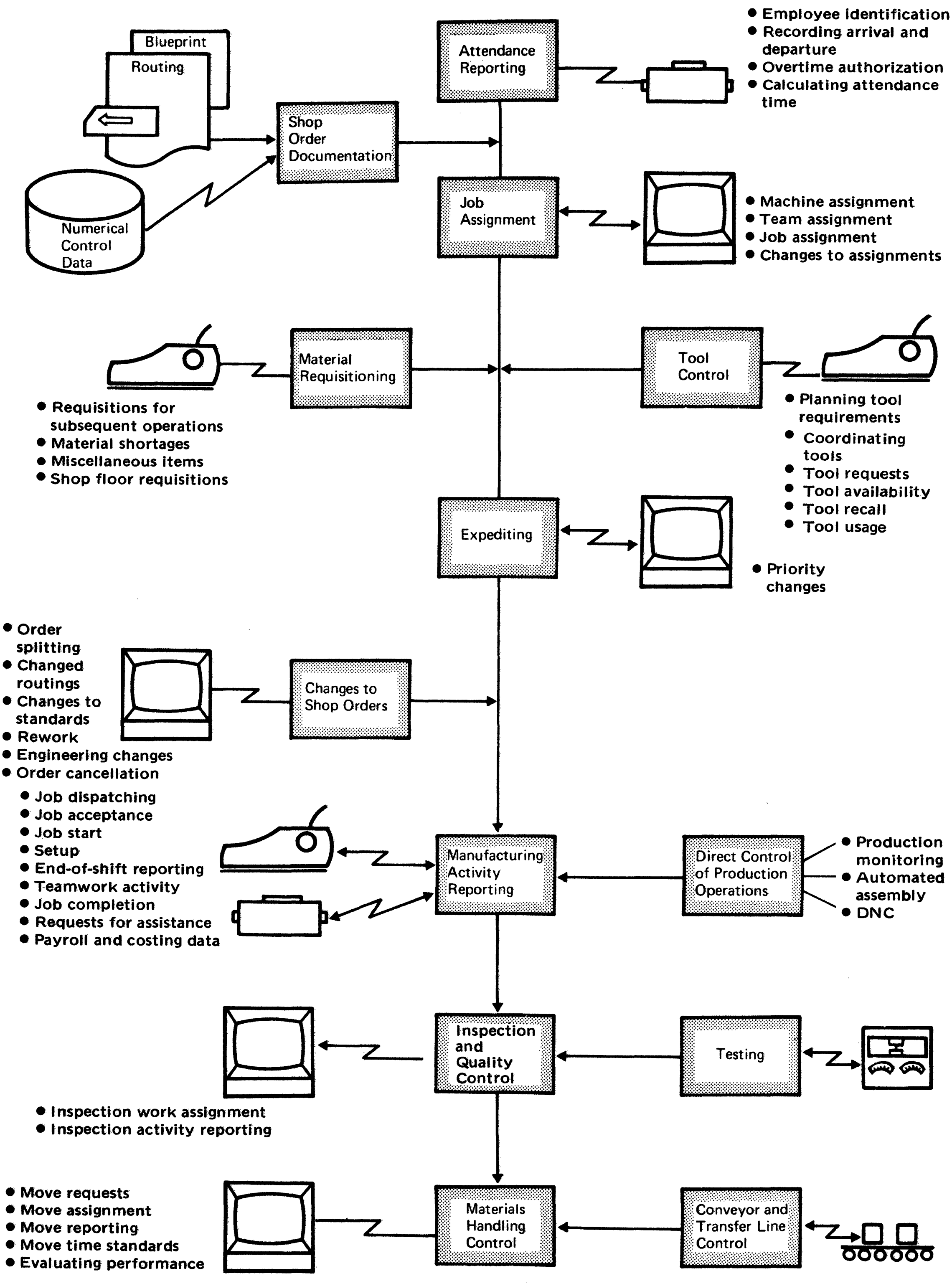


Figure 32. Basic functions of PLANT MONITORING AND CONTROL

FROM WC	SHOP ORDER	ITEM NO.	DESCR.	OPN. NO.	QTY.	SET -UP	OPN. TIME	NEXT WC	PLANNED WC	STATUS
610	43201	003204	SCRAPER	020	1000	0.0	3.5	753		IN OP
752	50043	220121	GRIP	080	500	0.4	10.1	752		IN OP
610	42964	003204	SCRAPER	020	1000	0.0	3.5	753	756	ASSIGND
653	42978	003210	SUPPORT	060	400	0.2	7.8	753		WTG. TOOL
752	30214	220121	GRIP	080	100	0.4	2.0	752		AVAIL
753	50417	003210	SUPPORT	060	400	0.2	7.8	900		TRANSIT

Figure 33. The work sequence list indicates the status of all shop orders now in a department or due shortly

- *Payroll and order costing.* The data required to maintain shop status is also used to meet the needs of the payroll department. Separate production and accounting transactions are no longer required. Job costing is a by-product of the system.
- *Inspection and testing.* The system's coordination capability gives improved control over shop floor inspection. Data for analysis can be fed directly into the computer via terminals, thus allowing earlier correction of off-quality production problems. Even tighter control can be exercised when computer monitored and controlled testing systems are incorporated into the manufacturing cycle.
- *Materials handling.* The system directs the movement of raw materials, work-in-process, tools, etc. Since foreman and workers no longer have to locate and negotiate for materials handling facilities, idle time caused by undelivered materials and tools can be minimized. Materials handling equipment – either manual, semiautomatic, or automatic – is better utilized.

- *Expediting and status reporting.* The need for expediters is greatly reduced. The system knows the exact location and status of all orders, machines, workers, tools, and materials. An increase in an order's priority rating ensures faster movement through its manufacturing cycle. The foreman knows about urgent orders well in advance, and can avoid expensive teardowns.
- *Tool control.* The tool storage area gets advance notice of tool requirements. This allows time for tool maintenance by taking into account tool room load and time needed for repair or reconditioning. In addition, if direct machine monitoring is employed, tool change notices can be automatically issued when the exact predetermined number of pieces have been produced. Unscheduled downtime can be used for changing tools whose remaining life is low.
- *Direct machine monitoring and control.* Traditionally, notification of various activities, such as job start, job finish, interrupts, piece counts, etc., has been accomplished by manual operator action. A production process can be linked to a computer located on the shop floor, or to a central computer by means of sensors. Continuous feedback of information to the computer helps solve a critical problem by supplying accurate and timely piece count, downtime reasons by machine, etc. Direct Numerical Control of machines is addressed in this section. In some cases, the computer also controls the process through direct links to valves, relays, stepping motors, etc., to automatically take corrective action, such as increasing coolant flow to solve a temperature problem, or adjusting cutter speed because of material hardness conditions. Examples of direct machine monitoring and control on the plant floor are illustrated in Figure 34.

Plant Maintenance

As labor costs rise, manufacturers invest more capital in sophisticated production equipment. PLANT MAINTENANCE helps extend the life of this investment, thereby reducing production costs.

The demand for shorter lead times and the frequent changes in the production plan require that the plant operate with as little work-in-process as possible. Yet modern techniques require specialized and highly interdependent production machines and facilities. This combination of low work-in-process and machine interdependence means that the loss of a key piece of production equipment for an excessive amount of time can sometimes virtually shut down a plant. Well planned preventive maintenance can keep such situations to a minimum.

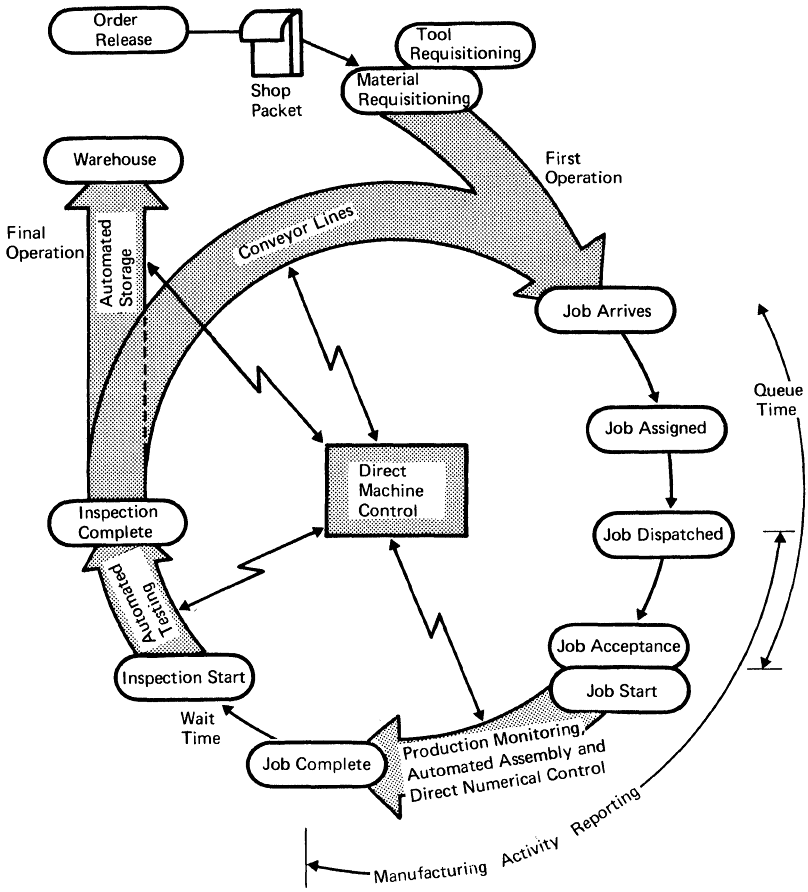


Figure 34. Examples of where direct machine monitoring and control can be used on the shop floor

The trend to more complex, integrated equipment means that maintenance can no longer be left only to the man on the machine – hence the increasing number of highly trained, highly priced technicians being assigned to the maintenance function. A maintenance control system ensures better use of this manpower.

Even though maintenance costs are increasing, the area has not been subject to as much management planning and control as the direct manufacturing areas. The difficulty in establishing tight control stems from:

- Absence of precise labor standards for maintenance work, which makes it difficult to use the same control techniques as for production

- A widely dispersed maintenance labor force, making direct supervision difficult
- High incidence of emergency repair work, which means that advance planning is difficult

With the aid of computers, however, maintenance costs can be effectively controlled. The techniques applied are similar to, and can be integrated with, those of normal manufacturing control.

objectives

The objective of computer-assisted maintenance planning and control is to reduce manufacturing costs by reducing machine breakdown and maintenance costs, while improving machine efficiency.

The basic premise of maintenance is: "It is better to prevent than to repair." However, increasing the frequency of preventive maintenance (PM) does not necessarily reduce total maintenance costs (Figure 35). Too frequent maintenance wastes material, manpower, and production capacity; too infrequent maintenance causes excessive downtime and leads to production inefficiency. The system helps determine the optimum PM interval.

Machine breakdown is not the only area where improvements can lead to savings. For example, inadequate PM causes production equipment

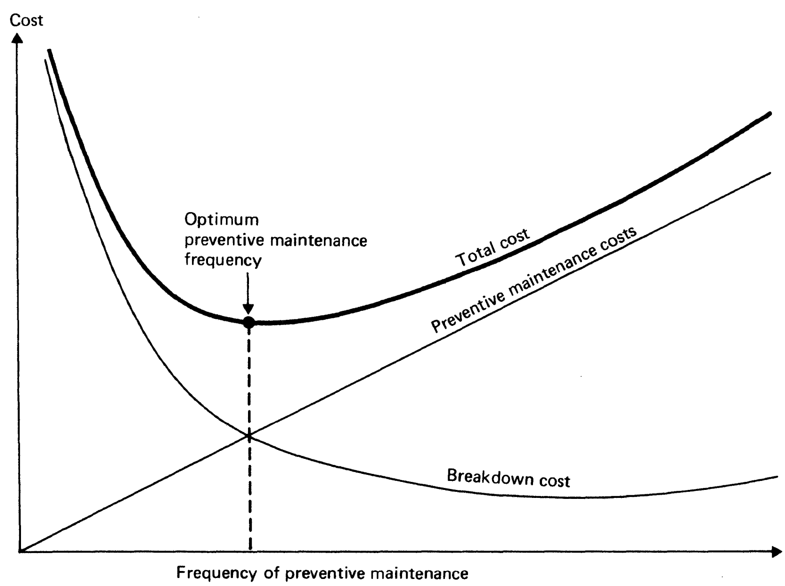


Figure 35. The cost of preventive maintenance is balanced with that of machine breakdown to get optimum PM frequency

to run less efficiently and also contributes to shorter equipment life. This results in operation of machines below the rated speed and increases the amount of time that workers spend on non-rated operations. Machine inefficiency also leads to lower quality and increased scrap.

In many companies, once PM intervals are set they are never altered unless excessive downtime occurs. This implies that most PM is performed too frequently. The system helps reduce this waste.

Maintenance costs can be further reduced through labor standards. The measuring of actual job time against reasonable estimates can significantly reduce maintenance labor costs.

Following are some of the functions addressed by PLANT MAINTENANCE (see Figure 36): system functions

- Assistance in establishing labor standards for repetitive maintenance
- Automatic scheduling of preventive maintenance
- Help in determining the scheduled maintenance interval, with the aim of reducing facility downtime and/or excessive maintenance costs
- Maintenance work order sequencing, on a priority basis, which reduces maintenance time lost waiting for the machine to become available
- Maintenance work order costing, which detects out-of-line maintenance or downtime costs and assists in evaluating purchases of equipment
- Establishment of the amount of standby maintenance labor required to service breakdown work orders

Purchasing and Receiving

In many manufacturing companies the essential areas of PURCHASING AND RECEIVING have not received the attention they require, because the complexities of planning and controlling production have been more obvious and have therefore claimed more management attention. Yet many production problems originate either from late supplier deliveries or from rejection of critical deliveries for quality reasons.

PURCHASING AND RECEIVING helps ensure that materials are available in the right quantity and quality when needed. Improved methods of following up purchase orders and evaluating supplier performance reduce the number of shortages and the acceptance of off-standard material.

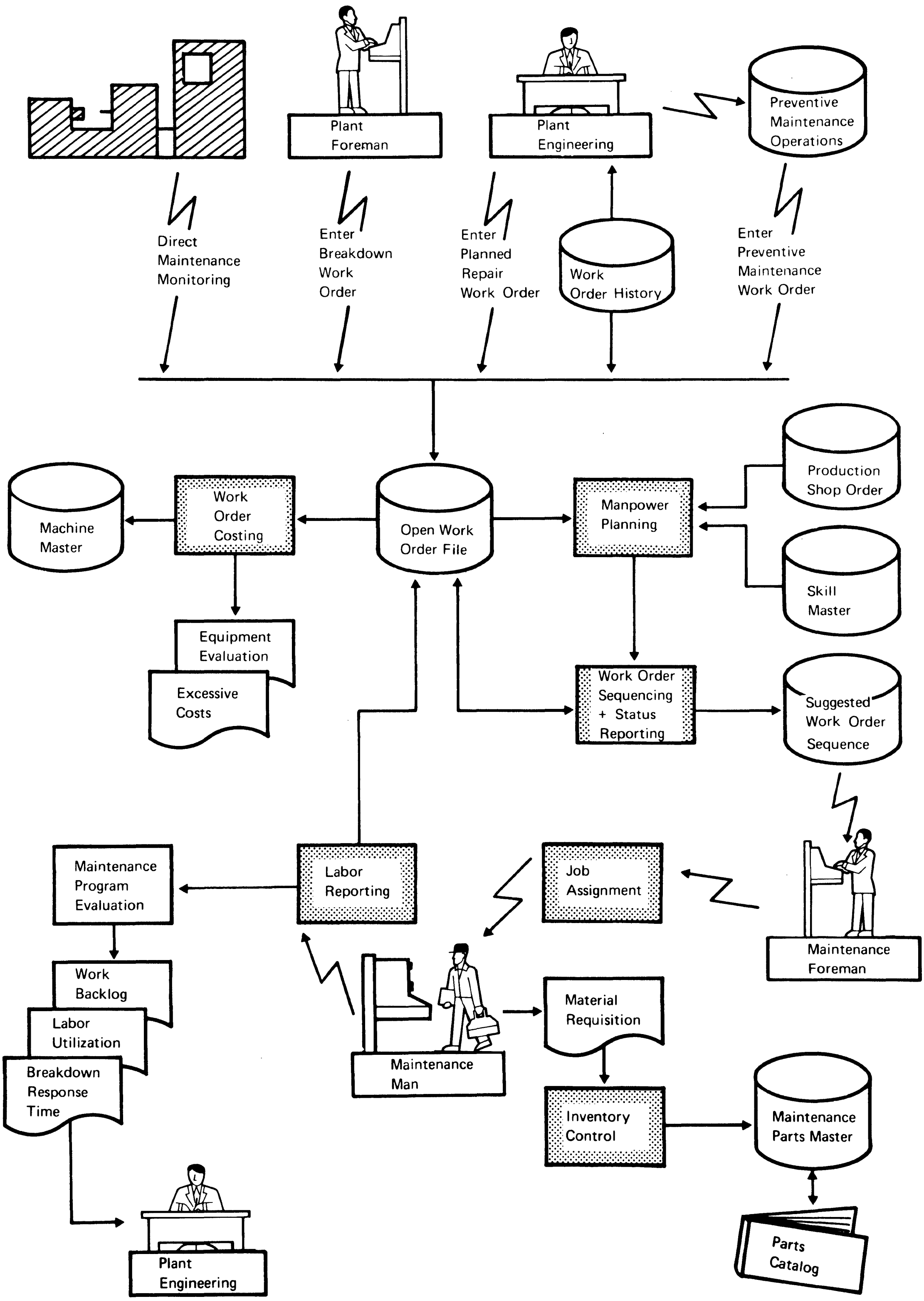


Figure 36. Basic functions of PLANT MAINTENANCE

Expenditure on purchased materials and services in manufacturing companies can account for 30% to 60% or more of sales. A small reduction in purchase costs can have a large effect on profits. When profits are squeezed by increasing costs and competition, the effect is magnified. Figure 37 illustrates the effect of a 2% reduction in purchase prices when profits are only 8% of sales. *The result is an increase in profit of 12%.*

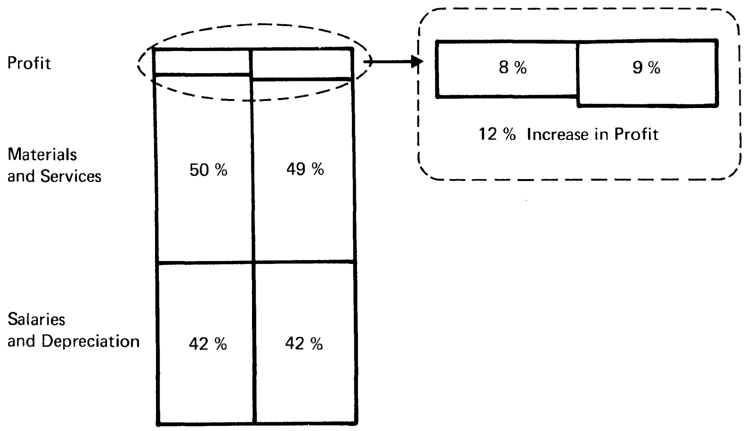


Figure 37. A small reduction in the cost of purchased material has a significant impact on profits

One of the major benefits of the system stems from better use of the buyer's time. The semiclerical activities that often take much of his time – searching for a copy of an order or trying to discover whether a delivery has been received – are reduced or eliminated. The result is that the buyer spends more time seeking lower prices and more reliable sources of supply.

The RECEIVING system is aimed at reducing from days to hours or minutes the elapsed time between receipt and storage of purchased items. Manufacturing and Purchasing are notified immediately of receipts of critical items. Allocation of these items to clear shortages can either be done by the system or be referred to the inventory administrator (Figure 38). The result is better use of the existing receiving facilities, reduced materials handling, and elimination of most recordkeeping by receiving personnel.

objectives

The objectives of PURCHASING AND RECEIVING are discussed in relation to the three major parts:

- PURCHASING – concerned with vendor selection and order placement and follow-up activities

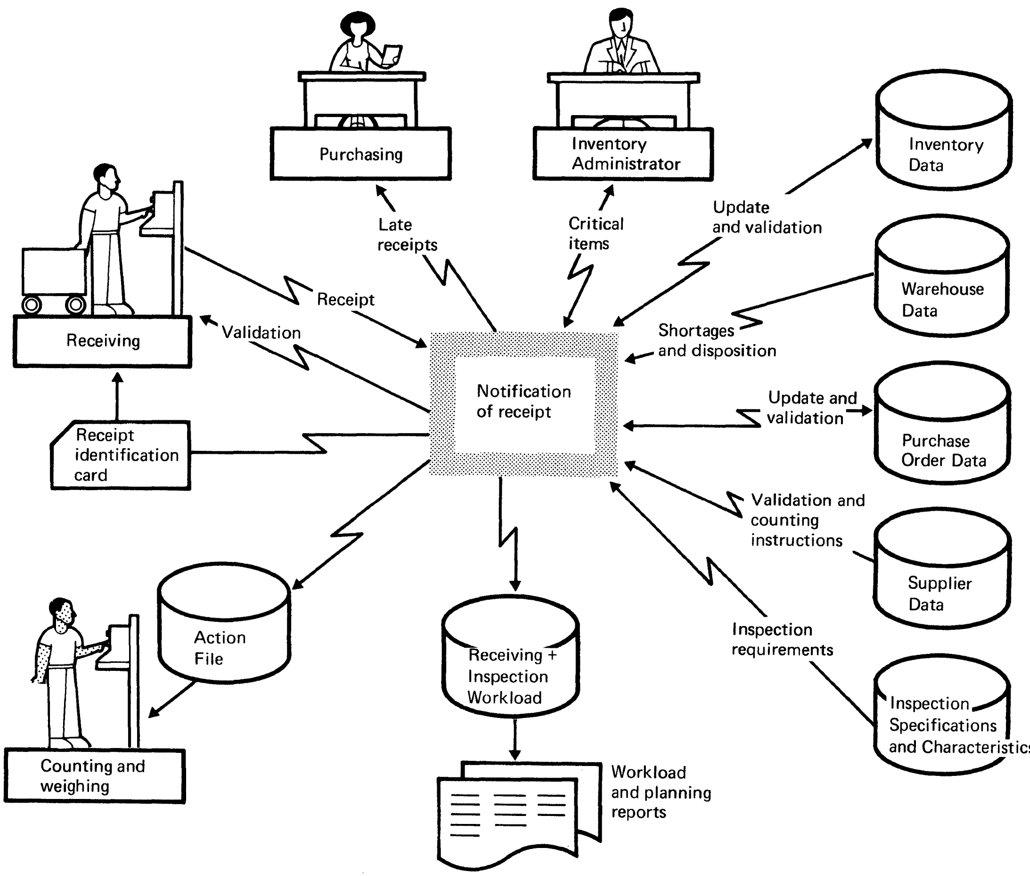


Figure 38. Manufacturing and Purchasing can be immediately notified of receipts of critical items

- RECEIVING – involved with identifying and validating receipts and routing the material through counting and inspection to stores or direct to the area where it will be used
- PURCHASE QUALITY CONTROL – concerned with inspection and acceptance of the order and control of rejected material

The objective of the system is to obtain the required quantity of material by the date specified on the requisition, at the lowest possible price consistent with the required quality level. To do this, the purchasing department must have time to evaluate an adequate number of suppliers for each item. For important items, current price and delivery quotations must be obtained from several sources of supply. Also, care must be taken not to overload any one supplier so that delivery is jeopardized.

Purchase orders must be followed up to avoid late delivery and consequent upsets to the manufacturing plan. The supplier's capability to deliver on time must be evaluated and delivery variations must be allowed for in planning.

Delivery of off-standard material can significantly disrupt manufacturing planning. Therefore, the quality of receipts must be measured against standards. Historical comparisons must be maintained to allow buyers to negotiate better performance from suppliers whose quality rating is drifting.

These objectives are interrelated. One supplier's low price may be offset by a less consistent or longer lead time, or a lower overall quality. To weigh such factors against each other, the system must maintain data on what items the supplier can furnish, his available capacity, and his historical price and delivery performance.

system functions

As illustrated in Figure 39, the major functions of PURCHASING AND RECEIVING are as follows:

- *Creating supplier and quotation data.* This includes reviewing supplier candidates, recording data about their capabilities (types of item manufactured, available capacity, etc.), as well as obtaining and approving an adequate number of quotations for each purchased item.
- *Supplier evaluation.* This involves recording and ranking individual suppliers' performance on the basis of price, on-time delivery, and adherence to quality standards.
- *Requisition entry and control.* This function has to do with the automatic creation of requisitions generated by ORDER RELEASE and the terminal entry of unplanned requirements for services and one-time purchases.

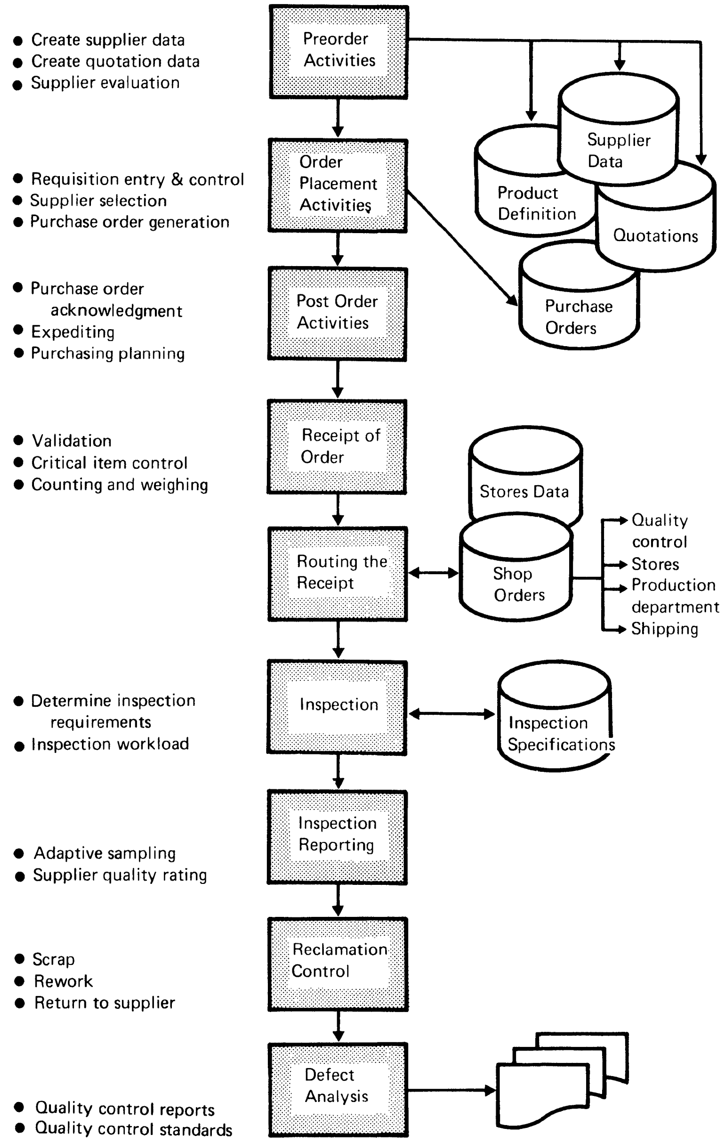


Figure 39. Basic functions of PURCHASING AND RECEIVING

- *Supplier selection.* A supplier with a good current rating is recommended at the time of order placement.
- *Purchase order generation.* This function includes both automatic generation of purchase orders and approval, via terminal, of purchase orders.
- *Purchase order follow-up.* This involves control of order acknowledgments, automatic confirmation, and procedures for making and controlling changes to orders after they are placed.
- *Purchasing department planning.* Information available from purchasing operations is used to measure buyer workload. The planning of purchasing commitments is also included in this function.
- *Identifying receipts.* How incoming materials are identified and verified against orders, despite possible missing information, is presented.
- *Validating receipts.* The quantity received is checked against the delivery documents and tested for reasonableness with respect to the quantity ordered.
- *Expediting critical items and shortages.* The buyer and the inventory administrator are automatically notified of the receipt of critical items. The relative priority of receipts is determined to ensure that they are processed in the correct sequence.
- *Routing the receipt.* This function determines where the items should be moved – for example, to stores, inspection, using department, reclamation, or back to the supplier. The location and status of all receipts is maintained so that items do not get lost or mislaid.
- *Inspection reporting.* This involves inspecting, testing, and reporting on the quality of items received and transmitting the results to PURCHASING, STORES CONTROL, and INVENTORY MANAGEMENT.
- *Reclamation control.* Status information on nonconforming items is provided to Manufacturing and Purchasing; the disposition of these items (accept or return to supplier, rework or scrap, etc.) is determined.
- *Defect analysis and supplier quality rating.* Defect information by supplier, item, and cause is analyzed. This information will be used to provide supplier analysis ratings and purchased part history as well as to determine future rejection allowances.

Stores Control

While INVENTORY MANAGEMENT regards inventory as sets of items measured in terms of quantity, STORES CONTROL regards it in physical terms with characteristics such as weight, volume, perishability, and physical location. INVENTORY MANAGEMENT and STORES CONTROL together create a complete inventory control capability.

In many cases, inventory control systems have not lived up to their potential because the physical storage aspects have not been adequately considered. The existing system must usually be overhauled to achieve the operating standards necessary for accurate inventory accounting. Physical control over stored materials is prerequisite to valid inventory management systems.

objectives

The major objectives of the STORES CONTROL system are to maintain close and accurate physical control over the company's inventories, to reduce the amount of materials handling within the stores, and to reduce the cost of storage.

The need for recordkeeping by storekeepers is greatly reduced. The system keeps track of where items are stored, and information regarding item quantities and locations is immediately available at the stores via terminal inquiry.

Inventory rotation is ensured, which reduces losses due to item deterioration – an important consideration in some industries.

Picking lists are generated by the system as late as possible in order to minimize the effect of changes. They can be produced in bin number sequence by storekeeper in order to minimize the number of trips made to each bin location (Figure 40).

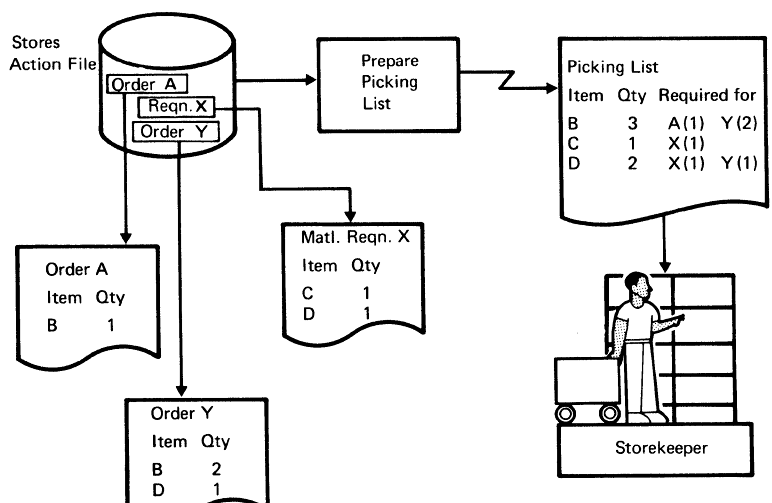


Figure 40. Picking lists are generated by the system from a number of orders and material requisitions

Better definition of the storage requirements of each specific item and of the individual stores facilities leads to improved physical handling and storage of items and allows the system to select the best location for each receipt from its inventory of available locations.

system functions

As Figure 41 indicates, STORES CONTROL involves the major physical and recordkeeping aspects of receiving, storing, and issuing stocked items.

- *Establishing basic disciplines* deals with the basic disciplines necessary for effective control over physical inventories. Improved transaction and documentation control, and identification of responsibility for transactions provide the level of accuracy necessary to support the remainder of the system.
- *Location control* matches item characteristics with appropriate storage facilities, with the aim of improving space utilization and labor productivity.
- *Order or requisition filling* improves the efficiency of picking activities and reduces the number of unplanned and unauthorized movements.
- *Automated warehouse control* is the application of the system to automated warehouses, with particular reference to high bay (stacker crane) storage techniques. A computer-based system enables the full potential benefit of this storage method to be developed, including the elimination of manual errors, improved item location, and increased storage facility utilization.

Cost Planning and Control

Few business decisions can be made unless the factors involved are expressed in comparative financial terms. Management's requirements from a cost planning and control system can therefore be summarized by the questions:

- What *should* it cost to make and sell each of the company's products?
- What *does* it cost to make and sell each of the company's products?
- Where do the variances occur, and how can they be reduced?

Providing the answers to these questions requires accurate information and creative financial analysis. This is mainly the responsibility of the company financial executive.

Among the financial executive's responsibilities is the performance of two major functions:

- Under the chief executive officer he carries financial responsibility for the company's assets and profits. This is, in effect, a policing role, the aim of which is to answer such questions as: What did it cost to make the product? Did we make a profit? Was this quantity produced and shipped?

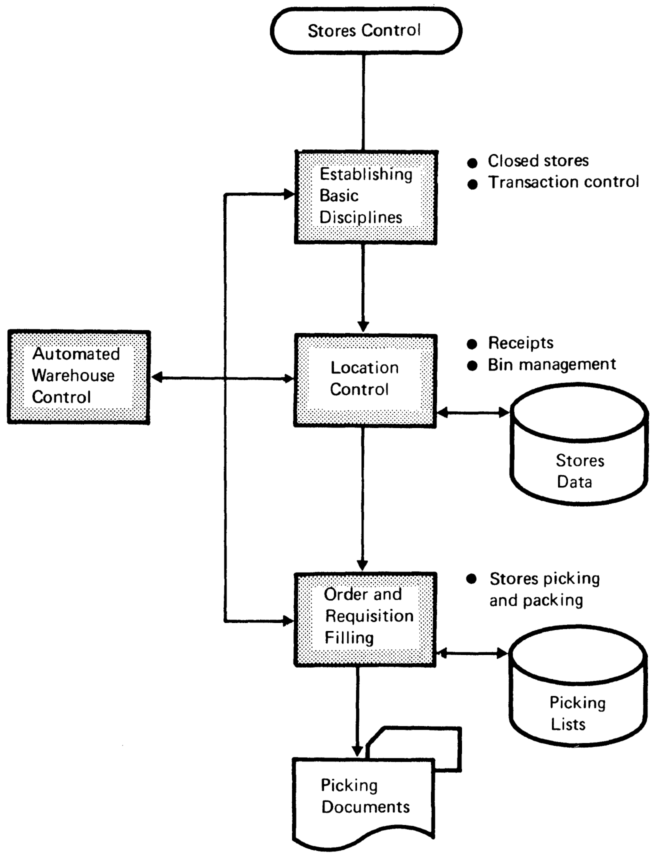


Figure 41. Basic functions of STORES CONTROL

- As the top-management team member who must evaluate management actions in terms of effect on profits, he answers an entirely different set of questions: What will it cost? How will this affect profits? Are we using this resource the best way?

In the first of these roles, the financial executive is concerned with the past; in the second, with a prediction of the future.

A major problem often encountered by the financial executive is the poor quality of the data provided by the rest of the organization. The information supplied by Manufacturing is often inaccurate and too late to detect problems in order to take corrective action. This does not mean that Manufacturing is at fault. Often, the immediate interests of Finance differ from those of the manufacturing departments. For example, the financial executive is concerned with inventory value, the cost of financing inventory, and the likelihood of obsolescence–in other words, with those items where there may be too much stock. Manufacturing people, however, are more concerned with shortages – in other words, with those items where there is too little stock.

Accounting personnel often attempt to solve the data accuracy problem by maintaining their own basic records. As a result, two separate inventory record systems are maintained. Neither, however, can be better than the transaction data received, and it is unlikely that the two systems will ever be in line.

One of the most significant advantages of COPICS is that it is an integrated system utilizing a common set of records, called a *data base.* The logic ties all the recordkeeping functions together. From recognition of the need to make a product, through planning, manufacture, and eventual shipment to the customer, each part of the system passes the information it develops directly to the next. This means logical checks on accuracy can be made. The objectives of the manufacturing departments begin to change when they use an integrated system. Instead of trying to solve each problem as it arises, they begin to operate within the constraints of a plan in which the important rules and policies have been chosen by top management.

objectives

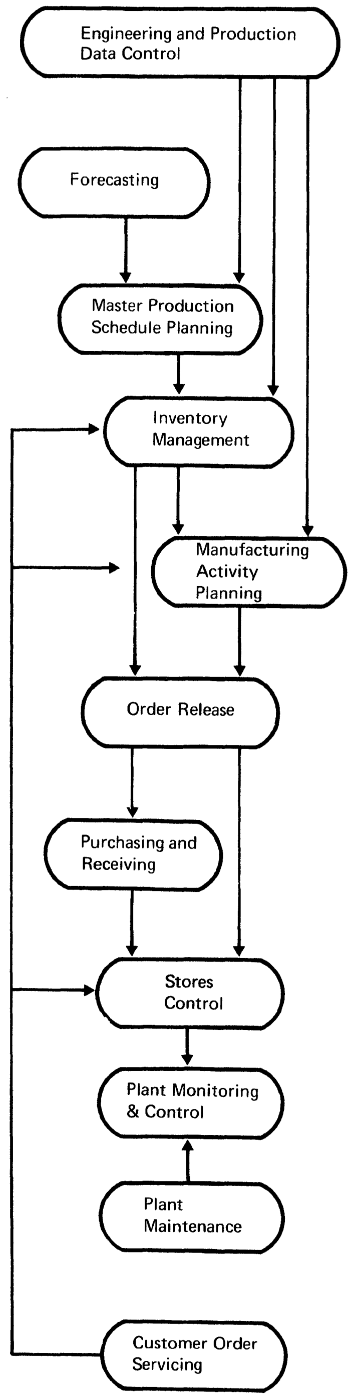
The objective of COST PLANNING AND CONTROL is to provide the financial executive with the capabilities he needs in his management role and with techniques which, although developed for organizing and managing production data, can also be used for managing cost and accounting data.

system functions

The facilities that become available to Finance when the system is installed are presented under the following topics:

- *Direct Labor and Material,* which includes planning direct labor and material costs, and controlling variances
- *Other Direct Costs,* which addresses the incorporation of some variable overhead costs in direct costs
- *Overhead Costs,* which involves apportioning overhead costs to departments and products, and planning and controlling departmental expense budgets
- *Allocating Company Resources,* which considers possibilities in the areas of long-range planning, capital expenditure, and work-in-process investment

All activities in a company provide information for specific functions of COST PLANNING AND CONTROL (Figure 42).



- Direct product costs
- Product cost changes

- Long range sales plan

- Long range financial plan
- Capital project planning
- Inventory cost forecast

- Overtime and shift costs
- Work-in-process costs

- Accounts payable

- Material control
- Job cost control
- Labor cost control
- Material cost control
- Maintenance costs

- Accounts receivable
- Sales information system

Figure 42. Relationship of manufacturing systems to COST PLANNING AND CONTROL

The commitment to real-time processing and to the concepts and principles stated in the COPICS chapters requires a significant investment in computer equipment and its supporting organization. However, the magnitude of this investment has been and is being significantly reduced. Analysts have observed that the cost of processing a transaction on a computer has been decreasing, roughly by 90%, every four years. Certainly this cost will continue to decrease in the future. The decrease in costs has been matched by a rapid increase in the capability of communications devices.

Some of the most dramatic improvements have been in the area of programming systems (so-called "software") supporting real-time data processing and large data bases. The low cost, along with the comprehensive capability of such systems in solving complex communication problems, brings real-time processing within the reach of most companies using today's medium-range computers.

Despite these improvements the investment is still significant. One of the objectives of this set of volumes is to indicate how this investment can be justified.

While most results of a communications-oriented system appear to be intangible, many specific benefits that can be derived from these results are very tangible – just difficult to measure in advance. The major benefits from applying the COPICS principles are:

- Reductions in inventories of finished goods, components, raw materials, tools, etc.
- An improvement in customer service. Fewer late orders, more realistic confirmation of delivery dates, faster delivery, shorter lead times, faster response to customer inquiry, etc., all should contribute to a better competitive position.
- Better utilization of production facilities. A slight increase in manpower and machine utilization can generate very large savings.
- A reduction in work-in-process inventory. This will result in shorter manufacturing lead times and less shop congestion.
- Higher productivity and quality through direct computer control of production activities.
- Better utilization of services directly supporting production, such as maintenance, tools, materials handling, and stores operations. Small decreases in these costs will contribute significantly to profits.

- Less handling of data. The need for paperwork creation and control is dramatically reduced.
- More realistic planning of manpower capacity levels, which will reduce overtime costs as well as idle time.
- Reductions in material shortages and in most of the resultant expediting.
- More accurate assessment of true product costs and determination of those factors causing cost trends.
- A reduction in the time lost because of production meetings to determine order progress and priority. The order priority system can easily be adjusted to meet changing needs, and the system helps ensure that the change is applied consistently.
- A reduction in purchased material costs because buyers have more time to spend in negotiating lower prices or seeking more reliable sources of supply.
- A significant reduction in the amount of systems effort spent on maintaining and changing old computer programs when new systems are implemented.
- The elimination of redundant system data. Everyone is basing decisions on the same set of data.
- Better utilization of a manager's time. He sees just the exception notices he has specifically designated as important, although further details are available immediately on request.
- More awareness of planning risks, more accurate forecasts, and more current information, resulting in better decisions.
- Reduction in a number of types of fluctuation through reduction in information processing delay. The smaller the fluctuations, the smaller the buffers needed to absorb them.

Justification for real-time systems should not be based on one isolated area such as labor reporting. The additional central computer costs and the terminal and transmission line costs may be difficult to justify when only one application area is considered. However, after the commitment to real-time processing is made, the initial expense incurred, and experience gained, the extension of real-time processing into additional areas requires much less investment.

System Requirements

Real-time data processing imposes new requirements on company management and data processing staff. Because of the wide scope of COPICS, the established principles of system design, implementation, and control are reemphasized in the next major section, *System Requirements,* under the following topics:

- *Management requirements* – the importance of management's role in implementing broad-based communications systems
- *Education requirements* – the need for extensive education in the use of the new system capabilities
- *Support program requirements* – the generalized program support available for real-time systems
- *System design requirements* – special features that must be built into the various system sections depending on the specific application
- *Conversion considerations* – factors affecting the speed and manner of conversion from existing systems to COPICS

Summary

The Communications Oriented Production Information and Control System (COPICS) presents new approaches to the communications problems facing manufacturing companies. It aids in the development of a common system by defining the functions of individual application areas, the general interfaces between them, and their basic data requirements.

COPICS is intended for managers. Emphasis is on nontechnical explanations of a systems approach designed to provide information in a form that manufacturing oriented people can use.

The application approaches presented apply to almost all manufacturing companies and cover the major problems from development of a forecast, through creation of the production schedule, to actual shipment.

The system flexibility and management controls provided allow a company to easily alter its policies to meet the changing demands of the business organization and its environment.

The emphasis of the application approaches is on material and resource planning, using a common data base and a communications terminal as a bridge between the computer system and the manager.

System Requirements

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Introduction

Real-time data processing imposes new requirements on management and data processing personnel. The wide scope of a communications-oriented system necessitates reemphasizing the established principles of system design, implementation, and control.

System Requirements summarizes the more important new requirements and old principles. The reader is assumed to be familiar with the basic terminology ("real time", "inline", "online", etc.), defined in *Management Overview.*

The following topics are discussed:

- Management requirements
- Education requirements
- Equipment (hardware) requirements
- Support program (software) requirements
- System design (application program) requirements
- Conversion considerations

Management requirements

This section emphasizes the importance of management's role in implementing a broad-based communication system. Management responsibilities include:

- Involvement in defining system requirements
- Full commitment to the system philosophy and policy
- Allocation of sufficient resources to accomplish the objectives
- Creation of an effective organization for implementing the system
- Establishment of control procedures to follow the progress of the implementation and to ensure that system objectives are met.

Education requirements

In this section the prime importance of education at all levels is stressed. Attention is given to training in the use of terminals and to education on the plant floor.

Equipment requirements

The basic functions of the terminals used to communicate with the system are presented in this section. The general requirements of the computer complex and the need for additional data storage are also covered. Special emphasis is placed on backup capabilities, which are vital in case of equipment failure.

Support program requirements

A large number of generalized computer programs are needed to support a real-time system. The major functions of these programs are:

- *Multiprogramming control.* This allows the simultaneous execution of several jobs.
- *Job scheduling.* Computer resources are allocated to the various jobs contending for their use.
- *Error control.* Data entry errors are detected and, if possible, automatically corrected.
- *Restart.* The system can be automatically restored to the status it had just before an equipment or program failure.
- *Data base recovery.* A set of data can be reconstructed if part of it has been lost.
- *Activity journaling.* All activities affecting the data base are recorded for audit trail and reconstruction purposes.
- *Data protection.* Security measures prevent unauthorized access to part or all of the data maintained by the computer.

System design requirements

Many system design and programming requirements are not of a general nature; they depend upon a particular application and are functionally described in the application chapters. Here only the following general requirements are discussed.

- *Action Files.* These control the exception notifications generated by the system.
- *Measurement standards.* Exception notification cannot be generated without effective standards for error detection and control. Incorrect standards can invalidate the whole system.
- *Terminal response time.* How fast is an answer needed?
- *Management-oriented design* of the system's briefing reports, displays, and terminal operation procedures.
- *Terminal training.* This should be initiated while the system is being designed.
- *Design, audit, and control.* New techniques have to be established with the help of auditing personnel.
- *Data base integrity.* Many systems perform less efficiently than they should because sound basic data is not provided.

Conversion considerations

The conversion of existing systems to the philosophy of the Communications Oriented Production Information and Control System raises some important questions:

- In multiplant operations, should data processing functions be centralized?
- Should a production application be performed in a batch environment before proceeding to a real-time processing?
- What applications should be addressed first?
- How fast can implementation proceed? How long will it take to install a system based on the COPICS concept?

Summary

System Requirements does not attempt to define everything needed for successful and profitable installation of computer-based systems. It emphasizes only some of the more important aspects, along with the relatively new implications of real-time processing.

Management Requirements

Surveys of computer-based systems have revealed that the degree of success in computer applications is in direct proportion to the amount of management involvement. The installation of a communications-oriented system demands from management:

- A commitment to the concept of real-time processing, and the communication of this policy to all areas of the business
- Participation in the definition of system requirements and objectives
- Allocation of sufficient company resources to accomplish the objectives
- Creation of a systems implementation organization that can effectively install broad-based systems
- Establishment of project management procedures which ensure that schedules are met, system functions are provided as specified, and budgets are met

Commitment to the Concept

The application areas addressed in this set of volumes touch virtually every aspect of the manufacturing business. These areas are closely interrelated; the data output from one is the input to several others. Erroneous data in one application can therefore cause problems in other areas.

Only *top management* has the perspective and the authority to make the commitment to a system whose functions are so highly integrated.

Because of the initial expense in establishing the centralized systems environment required by this type of processing, the manager of an individual area (say, Purchasing, Production Control, or Sales Order Entry) often has difficulty in justifying real-time data processing for his application alone, in spite of the benefits it offers. However, when the expense is spread over two or three applications, justification is much easier. The benefits are both tangible, such as a reduction in work-in-process, and intangible, such as a reduction in manufacturing lead time or the ability to simulate the effect of a number of different production schedules before committing resources. Only top management can determine the effect of these on the company's business.

The reason for this expense is that a communications-based data processing system requires:

- Larger computer "memories" to support the necessary control programs and the integrated application approach
- Faster central processing units to make feasible inline processing – for example, the updating of the work-in-process file as soon as shop floor activity is reported
- Additional hardware to provide backup in the event of machine failure
- Installation and control of communication lines (mostly normal telephone wires) throughout the plant
- Training of personnel in the use of real-time systems
- Writing, purchasing, or leasing the control programs necessary to implement such a system

The expenses incurred in meeting these requirements should be shared by all the business areas using the system. They should *not* be attributed to the first real-time application.

Justification of management commitment

To justify their commitment to such a system and to the associated expenses, top management must be convinced that the system will:

- Provide solutions to their problems
- Lead to a more profitable operation of the business

The intent of these volumes is to give the necessary assurance by analyzing the major problems and showing how they can be solved and with what benefits. Not all problems are addressed, but most of those not covered arise from individual local conditions and specific management requirements.

Most of the applications and techniques included in COPICS are now being used by some company; thus workable solutions to most problems already exist. These volumes attempt to show how all these techniques can be incorporated in a single system.

The system outlined *can* work, but whether or not it *will* work in a particular company depends on how well the project is managed. This, in turn, depends on the talents of the personnel assigned, the resources available, and the determination of top management to make the system successful.

The problem of economic justification is addressed by emphasizing the benefits in each application area. It is important to note that justification is generally based not on staff reductions (even though these can bring considerable savings in many areas), but on the more significant economies realized through reducing inventory, providing better service to customers, reducing work-in-process and manufacturing lead time, increasing production efficiency, and improving the utilization of supporting services such as materials handling, maintenance, and inspection. The value of these benefits must be estimated by an experienced top level manager capable of evaluating the full potential effect of the system. Individual managers will derive their own estimates and should be held responsible for achieving them.

Once the commitment to such a system is made, it must be communicated to all management levels. The full cooperation of all areas is needed if the system is to be installed with maximum success and minimum cost. Management must follow the project closely, issue periodic statements on progress, and constantly emphasize the high priority to be given to system implementation. All levels of management should realize that the introduction of the system heralds a "new way of life" and large potential benefits for the company.

Participation in Defining Requirements

The implementation of a business communications system should command the same degree of top management involvement as other major business decisions, such as product line expansion or investment in a major new production technique. Because most traditional business systems have suffered from a long period of inattention, the profit potential is huge. This potential justifies a very high management priority, yet in many companies development and implementation is left to the computer technician because system design is considered too complicated for management to comprehend and control. However, *only* management has the experience necessary to define the system's objectives: the assumption that the computer technician knows best is invalid. Determining who needs what, when and why, requires a perspective that only managers and application specialists possess.

When system design is left exclusively to computer technicians unfamiliar with the company's problems, the result is often a misapplication of computer techniques; the system is designed for the computer rather than for the manager. The resulting management disenchantment with computer applications may take a long time to forget.

Management involvement, therefore, is essential at every stage of system development and implementation. These stages include:

- *Recognizing the problems* to be solved and deciding which ones should be attacked first. Top management has to give the correct priority to each project.
- *Designing the system* to solve the particular problems, or giving detailed approval to a system designed by an application specialist.
- *Implementing the system* (this is not meant to include programming, testing, and documentation). The logistics of creating new data files, the training of personnel, and the method of conversion are prime concerns of management. In fact, more installation difficulties are caused by bad logistics than by incorrect computer programs.
- *Modifying the system.* After the system has been installed and used for a while, new requirements will become apparent. In addition, business objectives, conditions, and the managers themselves change. Implementing modifications demands the same procedure as system design – that is, problem recognition, design, and implementation. Management involvement must be considered a permanent requirement and not a one-time effort.

Allocation of Resources for System Implementation

There are few systems that cost less to implement than originally estimated, and even fewer that are operational on the date originally scheduled. This can be attributed to:

- Scope of the system, which is often so large that some design function is overlooked
- Overoptimism of computer technicians trying to justify their approach
- Underestimation of costs in the areas of, say, personnel training and program testing
- Difficulty in making accurate estimates of the time required for such creative work as system design and programming

It is a prime responsibility of management to allocate sufficient resources to the project. Many projects fail because of last minute rushes to meet schedules, or attempts to run applications on inadequately configurated computer hardware systems. At the same time, cost estimates should not be "padded", because costs will almost always expand to absorb the padding. However, it is usually better to have too much than too little.

The integrity of the computer specialists and the experience of the operational managers making the proposal are the best guarantees of the accuracy of a cost and schedule estimate.

Establishing the Implementation Organization

Good organization is a prerequisite for successful system implementation. The system functions should be organized to service all areas of the business. Because business communication systems cut across all business areas, there is no particular reason to assign a system implementation team to a specific area such as manufacturing or finance.

The importance of a computer-based information system, and the amount of money expended, may justify putting it under the control of a manager who has executive status. This is currently the case in many organizations.

The exact organizational scheme will vary between companies. Figure 1 illustrates one such organization. Titles vary, but a high level of responsibility is essential.

Computer service functions

With real-time systems several new or expanded computer service functions are required, demanding the following groups of personnel:

- *Communication network control,* often called "system integrators", whose functions include:

  Dealing with the suppliers of rented data-transmission services

  Constructing and maintaining each plant's internal network

  Coordinating service functions between the supplier and computer maintenance personnel

The last function is extremely important when trying to pinpoint responsibility for system malfunction. When terminals are geographically dispersed over a wide area, and many different terminal types are used, this control function is also concerned with maintaining the most economical network configuration from the standpoint of data transmission costs.

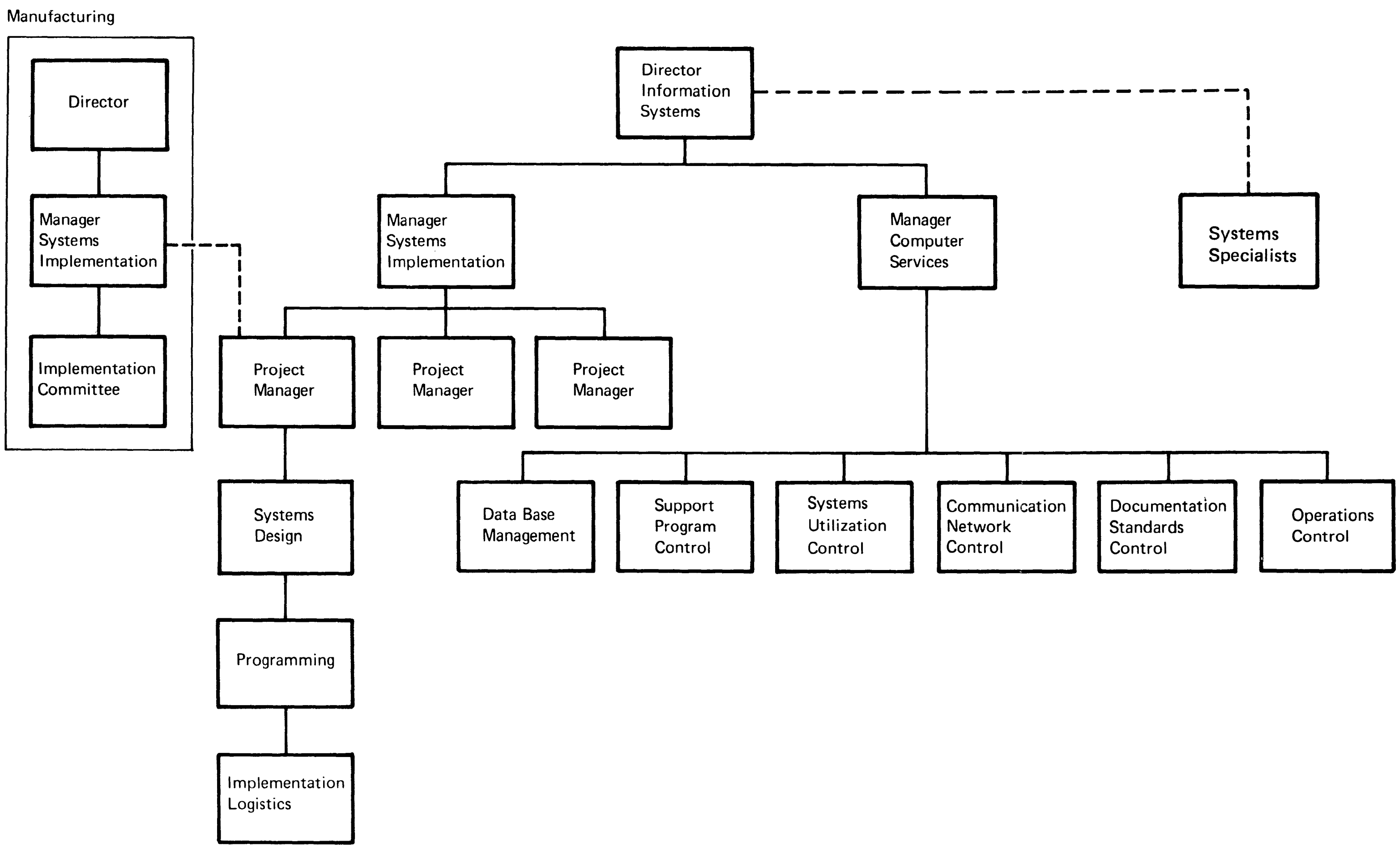

Figure 1. Information systems interface directly with manufacturing for application development and implementation

- *Data base management.* As new applications are added, the content of the data base usually has to be changed. The function of this group determines the most economical data base organization that meets system objectives. The data base concepts utilized by COPICS permit rapid and inexpensive alteration of all programs interfacing the revised data base. The coordination and implementation of such changes is also the responsibility of this group.
- *System utilization control.* Real-time systems impose unusual demands on computer facilities. The need for fast response to an inquiry or a data entry function is complicated by the fact that requests for service arrive at random intervals. This means that a backlog of requests can build up. At the same time, batch-oriented applications may also be using the system. Analyzing computer utilization and the speed of response (see "Response Time") is the function of this group of personnel. The result of such analysis should be computer configuration changes that provide the required response time at minimum cost.
- *Support program control.* The number of generalized programs written to support real-time systems is steadily increasing. These programs provide support for the operating system, the data base control system, and the communications control system. The support program control group is responsible for the configuration and maintenance of these systems and should also advise other groups using the support programs.

Project implementation

The most common method of preparing for project implementation is to assemble a team of systems, programming, and logistics planning personnel under a project manager. Thus, total responsibility for successful system implementation lies with a single individual.

One project manager may have several projects, including, say, long-range system planning, feasibility studies, proposal evaluation, system implementation, and revision of existing applications.

The project manager interfaces with the system implementation manager of the business area concerned. The latter, in turn, interfaces with an implementation committee responsible for defining and implementing changes in their specific area.

The project manager should have managerial rather than technical capability, since he must understand the problems of the particular application areas better than the functions of a computer. Managers with experience in the company should be considered for such posts even if they lack computer background.

An increasing number of companies are selecting a manager from the appropriate application area for appointment as project manager for the period of the project. Provided he is capable of managing and controlling both the application and the computer personnel involved, this arrangement has many advantages:

- He has extensive first-hand knowledge of the problems and requirements.
- He can secure the cooperation of the people in the application area.
- Since he will be operating the new system when he returns to his regular post, he wants it to be successful.
- He will take back with him a deep knowledge and understanding of the new system. He is the best man to install it and oversee the training of personnel in the application area.

Depending on the number of active projects, the project manager may report to a system implementation manager responsible for allocating systems and programming personnel to projects reaching various stages of development.

Systems assistance

The support of specialized personnel is vital for the successful implementation of real-time systems, since the concepts involved are relatively new to most organizations. Systems personnel to support the customer's organization in such new areas as data base management, support program configuration and control, communication network analysis and control, and system utilization can be extremely valuable. Support in specific manufacturing application areas may also be desirable. These specialists should participate in frequent system design reviews.

While the use of specialists can reduce training costs, help resolve peak-load implementation requirements, and reduce the lead time for system implementation, it is no substitute for the development of internal expertise. The decision-making responsibility must always lie within the customer organization.

Management Control Requirements

The need for effective project management cannot be overemphasized. The planning and control principles used in system implementation are not fundamentally different from those used to control other business projects. More systems have difficulty through lack of proper management than lack of technical skill. The effectiveness of a project manager should be measured by his ability to meet schedules and budgets while achieving the original objectives. A review by the managers using the system should reveal how effective a project manager is in meeting design objectives.

One of the biggest problems in evaluating progress is to break down the implementation effort into identifiable tasks. For effective control this is imperative, and it is especially important in large projects. It is much better to know that 85 out of 100 identifiable tasks are finished than to be told that "85% of the job is done".

Identification of the tasks allows the project manager periodically to check specific accomplishments and react to the changing situation. Manpower often has to be reallocated and schedules adjusted.

Many techniques are available for controlling the project. They are used to schedule the various tasks and at the same time to consider the interdependency of these tasks. Network planning methods using critical path techniques are very effective for larger projects. These techniques are supported by IBM computer programs.

Project management (project control) programs

Two stages are involved in project control:

- Creation of an efficient, feasible plan
- Monitoring of progress and revision of the plan as necessary

creating the network

The user of a project control program must first devise a "network" representing the activities involved in the project. During the planning phase each activity is identified and its duration is estimated. The activities are built into a network in which each one is immediately preceded by those that must be completed before it can be started. The completed network, therefore, has a large number of activity "paths" between the start and the finish (Figure 2).

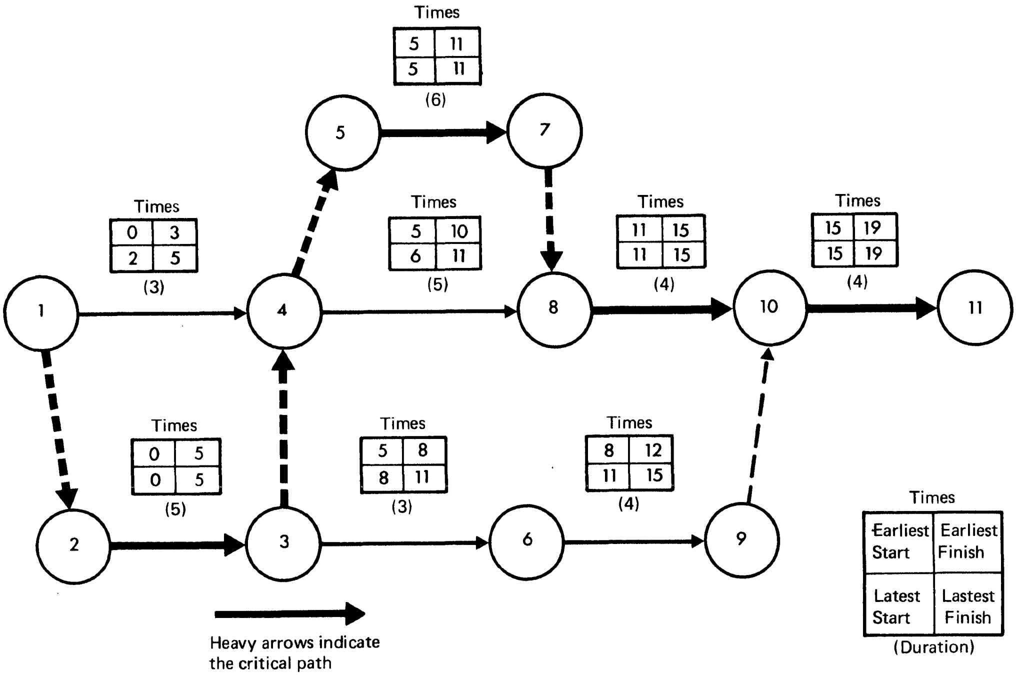

Figure 2. Project control programs that use critical path techniques improve both planning and execution

Processing involves following each path from the project start to determine which one has the longest duration. The earliest possible start date for each succeeding activity is thus derived. The reverse process, starting from the completion of the project, determines the latest start date for each activity.

The ability to turn this initial plan into an efficient planning tool is based on the fact that differences between earliest and latest start dates, representing "slack" time in the project, indicate activities that are not critical to the timely completion of the project. There will be, through the network, at least one continuous path of activities (called the "critical path") in which the earliest and latest start dates are the same; these activities determine the project completion date. If the completion date is to be advanced, either the times or the organization of these activities must be improved.

There are several advantages to this method of project control at the planning stage, when the network is first established:

- Creation of a network necessitates detailed analysis of the project, which results in a better plan.
- The critical areas of the project are identified. These areas may not be those expected to cause problems.

- By improving the sequence and organization of activities on the "critical path" and reprocessing the network, an optimum, achievable plan is obtained.

revising the network

A major part of the benefits obtainable have already been realized: better discipline in planning, and concentration of management activity on the critical areas of the project. However, the adjusted network can now be used to help solve the project manager's second major problem, that of controlling the project through its life. As activities are completed they are removed from the network. Estimates of the remaining activities are revised, and the network is periodically reprocessed, with a new completion date and list of critical activities generated. Any change in the completion date can be related to the activities on the critical path that caused the change. Lists can also be produced that identify the responsibility of each resource or department, in each time period, throughout the project. The project manager knows where his problems are, who is responsible for them, and the magnitude of their impact on overall project status.

Very large projects can be controlled as single networks, or as a series of separate networks, linked together wherever they affect each other. A complete phase of the project that cannot be well defined at the start of the project can be included as a single activity and can be developed into a subsidiary network later in the project life, when better control over it is needed.

The processing of networks involves no more than simple arithmetic. Because of the volume of processing in a large network and the value of frequent reprocessing, however, the computer is an ideal means for handling networks. When a computer is used, a more complex analysis can be undertaken that adjusts activities within their available slack time, with the objective of averaging the demand for each resource. Resource allocation provides information of great value to project managers.

Summary

The importance of management participation in system design and implementation cannot be stressed enough. If this participation is to be effective, managers must educate themselves in basic computer concepts and capabilities. COPICS should be of considerable assistance in this area. Once knowledgable, managers must directly and constantly participate in system design and implementation.

Top management must make the overall commitment to real-time systems, because individual functional groups do not have the perspective or the resources to justify the overhead cost. The high priority of this commitment must be continuously communicated to lower-level management.

Top management must establish the proper implementation organization and must insist that effective project management control techniques be applied. This, together with the commitment of sufficient resources to accomplish the objectives, should ensure effective implementation.

Education Requirements

Management Education

The intent of the Communications Oriented Production Information and Control System is to provide major assistance to managers in the area of problem recognition and system design. Management must also accept the responsibility for becoming knowledgable in basic computer and system concepts. These topics are the subject of many courses available at the executive level; application-oriented courses are also offered. The knowledge gained in these courses, plus an understanding of the COPICS concepts, will enable executives to communicate successfully with their computer and systems staff.

Top management must ensure that all managers become familiar with the overall systems approach. Only when each manager sees where he fits into the whole system will he appreciate it and willingly cooperate in its installation. Most managers resist the implementation of a system that they have not helped plan.

In most cases the objectives of a system are limited by how much company managers understand and, consequently, how far they are willing to go in implementing a comprehensive information and control system. Greater knowledge leads to more realistic and ambitious system objectives. The more realistic and ambitious the initial objectives, the smaller the need for costly revisions.

Employee Education

The importance of education, not only to managers but to all employees throughout the company, cannot be stressed too highly.

Educating does not have to be done by data processing people or people outside the company. In fact, it is preferable for it to be done by line managers or key employees. Shop floor operators respond better to one of their own people than to a computer "expert" telling them what to do.

One of the basic problems is that although people may see a benefit to the *company* as a whole, they do not see a benefit to *themselves* or their department. A reduction in work-in-process and in manufacturing lead time is good for the company, but what does it do for the operator?

The line manager can tell him this, whereas a data processing technician may not be able to – at least not in shop floor terms. The type of education that can be provided for the installation of PLANT MONITORING AND CONTROL, described below, can serve as an example.

Plant floor education

The first task is to set up a project team responsible not only for designing and installing the system but also for educating shop management, key personnel, and union representatives. Once these people have received the necessary instruction, they, in turn, can be instrumental in informing the rest of the shop.

project team

The project team should consist primarily of responsible people recruited from the plant – for example:

- A shop foreman or supervisor
- A production controller
- A union representative

The team should be augmented by one or two people from data processing, preferably with shop floor experience.

Once instructed in the principles and objectives of the proposed system, the project team can realistically assess it in terms of the following and other benefits to the departments and individuals:

- Fewer interruptions from expediters and fewer "teardowns" on the machines
- Less idle time for the individual
- Better planning of overtime work
- Less waiting time for tools, materials, drawings, and so on
- Less paperwork for the foreman
- Less "chasing" of parts through the shop
- Less time spent in production meetings
- Faster response to a request for help, such as for a maintenance man, materials handler, or foreman
- Better knowledge of what work is coming, and when, which means that work will not be subcontracted because of an overload this week, when next week the shop will have idle capacity because of lack of work

foremen, union representatives, key personnel

The concept of the whole system, rather than just PLANT MONITORING AND CONTROL, should be explained to shop management, union representatives, and key personnel. This is a worthwhile "public relations" exercise in outlining the company's problems and the way in which the system is being installed to help solve those problems.

It can help dispel any shop management fears that the system is just another hindrance to their job of increasing productivity. It can also allay any labor fears that the system is just another method of checking on the workers.

The instructor should explain the system in detail, showing the types of transactions to be made, what the system does, and what is required of all personnel. A good technique is to "play act" what would happen on the plant floor, emphasizing all the mistakes that can be made and the way in which the system can detect and even correct these mistakes. This personalizes the proposed system and can lead to many improvements. As class members make suggestions and see them incorporated, the system becomes their own, not something imposed upon them.

shop floor personnel

Educating every operator, materials handler, inspector, etc., in the company is a big task, but worth all the time it takes. It pays large benefits later in terms of reduced errors and smooth running of the system.

Again, an introduction to the overall system helps create a sense of involvement. This will probably be the first time these people have been told about the complete company operation, and they will appreciate not only the part they can play in making it more efficient, but also the benefits outlined above which they personally can gain.

"Play acting" here too can be used to demonstrate what will happen when the system is running. The project team, being composed of shop floor people, is able to answer any queries and dispel fears – for example, by emphasizing that the system is designed to check on *jobs,* not on *men.*

Installation of the terminals

Education does not stop with system installation. No matter how well people have been educated in advance, they will make mistakes in actual operation.

Terminals should be installed in the shop a week or two before the system is due to go "live". If operators are encouraged to try out the terminals during this period, much of their fear of something new is dispelled.

Once the system starts in operation, an experienced man should be located at the terminal to help people if they make mistakes.

Summary

Education is essential to the smooth installation of any system. This section has presented a method of instruction in just one area of the company. Other areas can be tackled similarly. In many areas the system itself can help in the education. In CUSTOMER ORDER ENTRY, for example, new operators can be "walked through" the system by simulating the entry of orders. As they make mistakes, the system outlines their errors and takes them through a retraining in the particular part of the entry procedure involved. Once they have mastered this part, they go on to the next phase of order entry.

Equipment Requirements

Real-time computer systems use basically the same equipment as batch-oriented systems. However, there are extra requirements such as communication terminals and communication line control devices. Additional requirements are also imposed on certain functions of the computer complex. In particular, extra storage facilities and equipment backup are necessary.

Communication Terminals

A terminal is a device by which an individual can communicate with the computer from a remote location via telephone-type line facilities. There are several basic terminal functions and they can be combined in a variety of ways. Computer programs are designed so that a relatively inexperienced terminal operator, with no knowledge of computers and little knowledge of the overall system, can communicate with the machine. The system monitors all terminal activity and immediately detects errors or unauthorized attempts to obtain access to information.

Input devices

Variable Data Entry. Entry of data that is not known in advance (say, production quantity) is made via a variable data entry device. The most common types of these devices are illustrated in Figures 3 and 4.

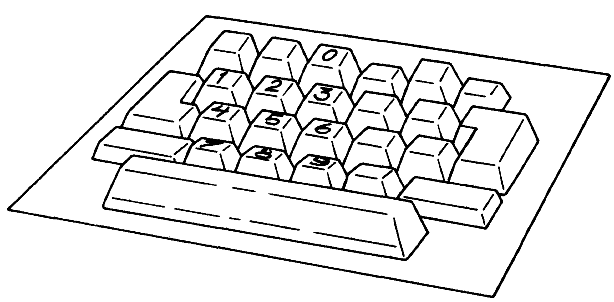

Figure 3. Ten-key keyboard for entering numeric data

Figure 3 shows a ten-key keyboard used for the entry of numeric data. Figure 4 shows a full keyboard used to enter alphabetic data. It is almost identical in layout to a typewriter keyboard. Some special keys may be designed as "function keys". In this case, a depression of just one key can initiate a predefined action whenever required. The requested action might be "display all production machines not running" or "list all open purchase requirements to be approved".

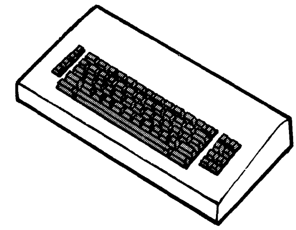

Figure 4. Keyboard for entering alphabetic and numeric data and special characters

Other types of variable data entry include switches, dials, etc. These are used particularly on shop floor terminals and are described in *Chapter 8, Plant Monitoring and Control.*

Complex transactions may require several entries of variable data, but there is no limit to the total amount of data that can be entered.

Fixed Data Entry. Fixed data, normally used for identification purposes, can be permanently encoded into punched cards or prepunched plastic badges (Figure 5). The card or badge accompanies the item (or man) it identifies, for example, a shop order, a quantity of parts issued from stores, or an employee. Some inexpensive terminals can read ten positions of identification data, while others can read an entire punched card. Usually ten digits are sufficient for a single transaction. Fixed input identification should be used where possible, because it reduces both data entry time and the number of errors.

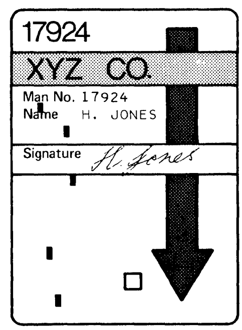

Figure 5. A machine-readable plastic badge

Direct Digital Entry. Instruments such as counters, attached directly to a production machine tool, can initiate signals acceptable by a terminal. Such instruments are used for monitoring production count, machine on/off status, etc. This is described more fully in *Chapter 8, Plant Monitoring and Control.*

Light Pen. Information can be entered via a light pen used in conjunction with a visual display device (see "Output Devices").

Output devices

Visual Display. Terminals of this type use a cathode ray tube (as in a television set) to display output at high speed. A complete screen of data can be displayed in a few seconds. Associated with such a device normally is a keyboard that enables the operator to use the terminal for input as well as output. Alternatively, input can be "transmitted" by indicating selected items on the screen with a light pen (Figure 6).

Visual display devices do not produce printed copy, but this is unnecessary in many situations. When necessary, remote printers can be attached for printed output. Visual display devices are invaluable in cases where fast communication is necessary.

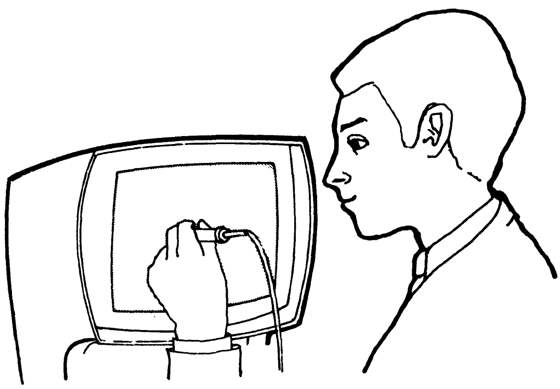

Figure 6. A light pen can be used to draw or enter data onto the screen

Printed Output. When there is need for "hard copy", it can be prepared on a variety of terminal devices. Hard copy is required to authorize such activities as the release of a shop order, a material move, a maintenance assignment, or the picking of components in the warehouse. Terminal printout devices can be classified by speed:

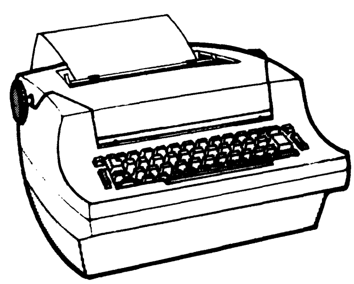

Figure 7. A low-speed printer that can be on the shop floor

- Low-speed printers (Figure 7) resemble typewriters and print at a speed of 8 to 15 characters per second. They are used where a relatively small amount of printing is done. Normally they have a full keyboard associated with them and can therefore be used for entering data as well as receiving it.
- Other printers, operating at a speed of 100 to 2000 printed lines per minute, are used in situations requiring a large volume of printed output. Examples are the printing of manufacturing routings, stores picking lists, and purchase orders.

Some hard-copy terminals have an "intermediate data storage" capability: when the data is entered, it is not transmitted directly to the computer, but is temporarily stored on paper tape or magnetic disk. When sufficient data has been accumulated, it is transmitted in batch mode at a high speed (independent of the operator's keying rate). This technique is advantageous when the transmission line rental costs preclude continuous online operation. Customer order entry from widely dispersed sales offices is a good example.

Punched Cards. Output may also be directed to a card punch. Punched cards are normally used for identification purposes; for instance, a card accompanies a shop order and is used to establish the order identity whenever data for that order is transmitted from terminals in the shop. The information punched is also printed on the card. Punched identification cards can also be prepared in advance for tool requisitions and purchased material receipts.

Audio Response. Output at a terminal can be in the form of an audible message transmitted via a normal pushbutton telephone or other audio response terminals. The ten-button keyboard on the telephone is used to enter variable data. Some terminals can also read an encoded plastic identity card. The audible message is constructed from a vocabulary of recorded words and syllables stored on a magnetic drum. The words and syllables are automatically sequenced by the computer, which composes an understandable human-voice statement such as:

PART - - NUMBER - - ONE - OH - FOUR - FIVE - TWO - - ON - HAND - - BALANCE - - ONE - HUNDRED - SIXTY - SIX.

The advantages of this approach are that it transforms an inexpensive telephone into an inquiry terminal, and that existing telephone networks can be used. Its disadvantages are its slow speed, limited length and vocabulary, and inability to produce hard copy.

Physical Signals. The system can also activate certain physical signals, such as flashing lights or audible horns. Such signals can be used, for example, to warn a foreman that a machine tool is down or an operator has run out of work.

Operation simplicity

The most important consideration in the design of terminal operations is simplicity. Even computer efficiency should be sacrificed to this end. COPICS presents terminal usage methods and system approaches that minimize the amount of data to be entered. This simplifies training requirements and reduces data entry errors. Typing skill is generally not required to operate terminals, but is desirable in certain cases, such as entering a customer order. In such cases, data entry is normally performed in a clerical center where such skill is available.

Computer Storage Requirements

The installation of a communications-oriented system demands a computer complex with increased main storage (where the program is executed) and increased secondary storage (where most of the data is stored).

Main storage

One of the reasons for increased main storage requirements is the need for additional control program functions (Figure 8). Normally these programs are kept permanently in main storage. Their functions are detailed under "Support Program Requirements".

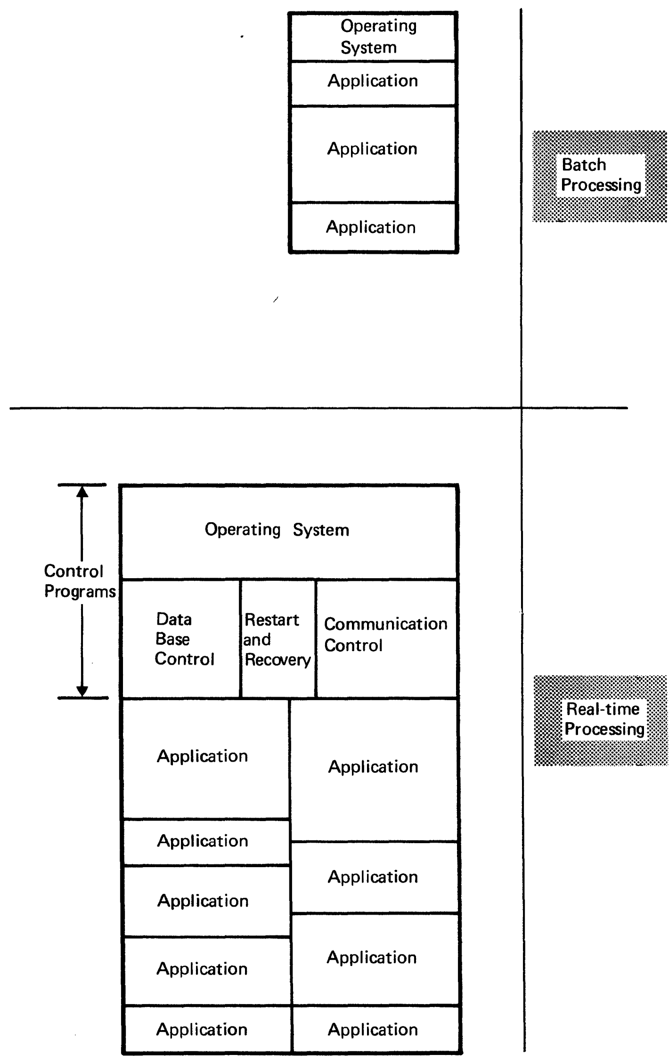

Figure 8. The number of programs in the computer's main storage at any one time is increased in real-time systems

Control programs include:

- Programs to control the communication network – terminals, communication lines, and transmission control units.
- Programs to manage the allocation of computer resources to the various application programs. Use of these resources is scheduled on a priority basis. These programs are called "operating systems". Although such programs are also required in batch-oriented systems, the increased number of facilities and programs in a communications-based system demands operating systems of greater size and versatility.
- Programs to manage the system data files and the retrieval of information from them. These programs have to be more extensive in order to handle the larger amount of data processed by a real-time system.
- Programs to facilitate the restart of the system in case of a computer or program failure.

Another reason for the increase in main storage capacity is the need to accommodate more application programs at any one time. Data entry transactions and inquiries from the shop floor are made many times a minute. The application programs processing these high-volume transactions are usually kept in main storage at all times. This allows a faster response. It also avoids the waste of computer resources that would result from the repeated reloading of the application program into main storage.

The main storage requirements for installing COPICS will vary greatly from company to company because of differences in volumes, response time requirements, and application programs.

Secondary storage

Most transaction processing programs (real-time application programs) must give a fast response to the individual using the terminal. The data required by the programs must therefore be stored on devices that permit fast random access to any portion of it. These devices include magnetic drums and magnetic disks (Figure 9). Normally all these types are used in a real-time system. Programs that cannot be held in main storage all the time but are constantly used may be stored on magnetic drums. Normal operational information like inventory data, routings, shop and purchase orders, etc., is kept on disk files. Historical data, less frequently required, can be stored on other devices, such as magnetic tape.

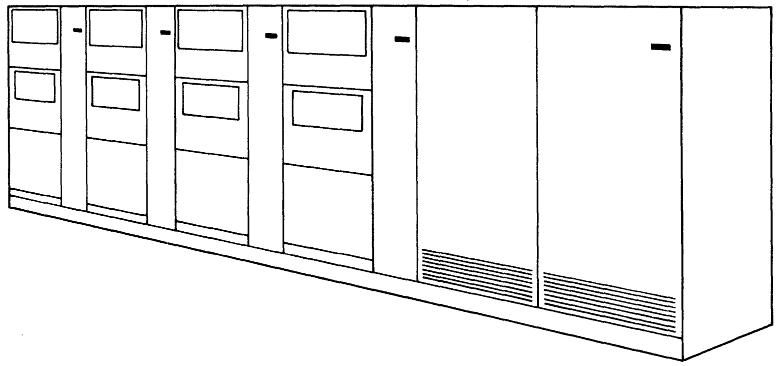

Figure 9. Random access storage devices provide rapid access to the data required by a real-time system

The data base support programs outlined in *System Data Base* allow the storage of various portions of a single set of data on different devices. For example, data concerning the progress and status of a shop order may be kept on different types of devices. The operation now being or about to be performed is recorded on drum storage; the operations yet to be performed are recorded on disk storage.

Computer Requirements

The implementation of a COPICS system does not demand that all data processing be centralized on one computer. Portions of the data and certain application functions can be transferred to smaller "satellite" computers located on the shop floor. Other plants may also have their own computer systems and link them to the central system.

Plant floor computers

The satellite or plant floor computer may handle transactions particular to one area of the shop, or directly control a production process, a number of machine tools or an automated warehouse system. These small computers can be linked via transmission lines to a large central computer complex (Figure 10) or can be used by themselves ("standalone").

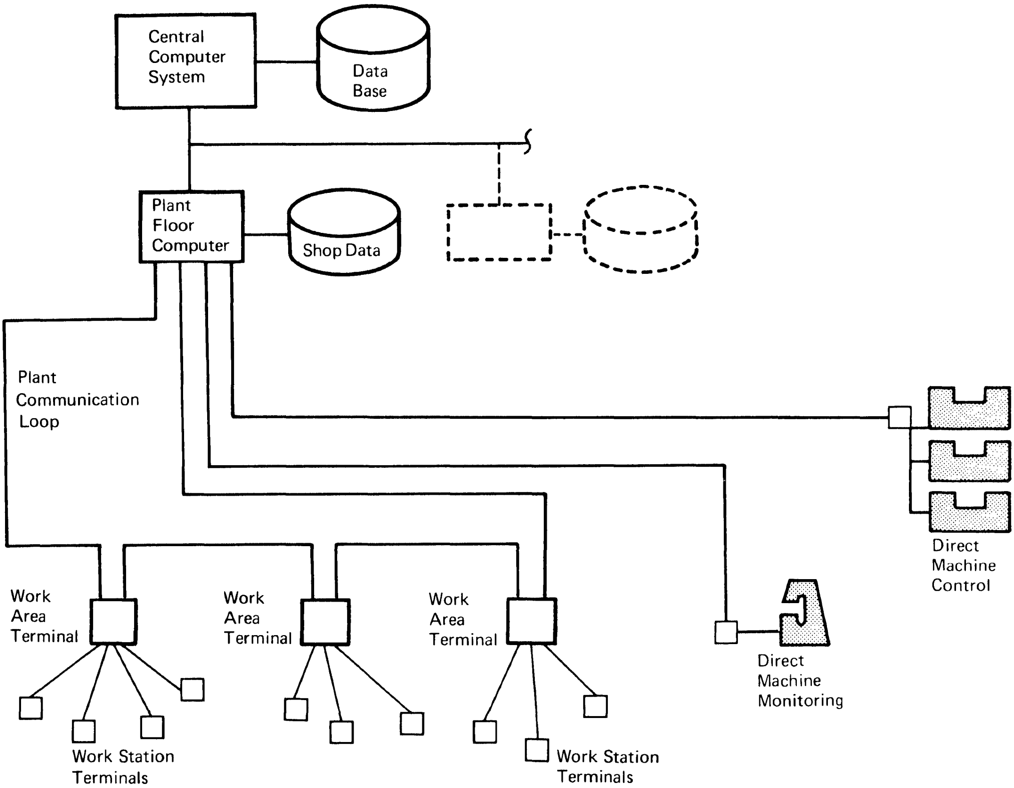

Figure 10. Plant floor computers can run local applications while collecting and transferring data between shop floor terminals and the central computer

The use of plant floor computers to support the central complex offers several advantages:

- Transactions not requiring fast processing can be accumulated by the small computer and fed to the large computer during lulls in processing. This levels out the load on the large computer and reduces equipment costs. For example, transmission of transactions involving only the local department (such as a change in machine assignment) or of those not requiring central coordination (such as completion of a setup) can be delayed without sacrificing system performance.
- Equipment backup costs (see "Equipment Backup Requirements") can be reduced. If the large computer is temporarily not available, the plant floor computer will have enough data and enough capability to keep the department running on a normal basis for some time. Also, the low cost of the smaller computer justifies its installation as insurance against failure of one of the other computers.

direct machine control

Plant floor computers are designed to provide direct control of machining processes, materials handling (conveyor control), and automatic testing equipment. In many cases, therefore, they can perform both normal transaction processing and direct computer control of production activities. Dual usage reduces equipment costs.

Multiple plants

The same principle can be applied where multiplant operations are involved. Each plant can maintain its own data base and use its own computer to process its own application programs. The central computer coordinates the activities of all plants and provides the necessary exchange of information. The secondary computer can be linked to the central computer via data transmission lines (Figure 11).

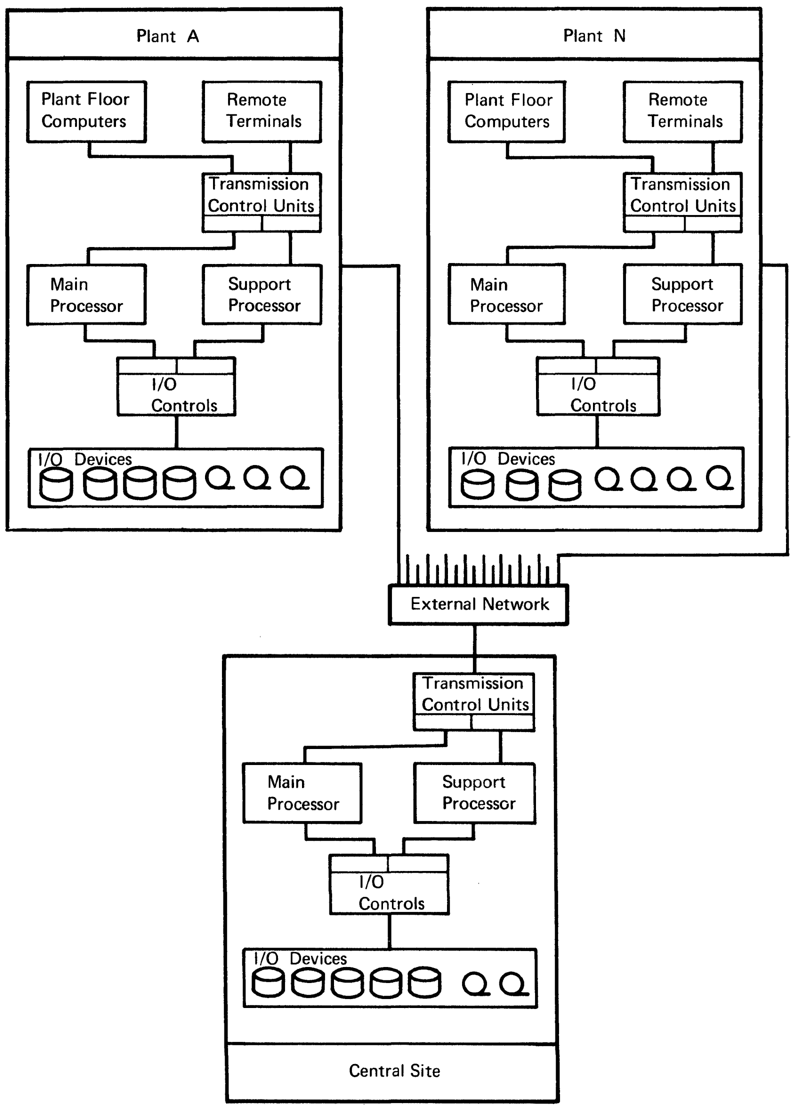

Figure 11. Individual plants may have their own computers linked into the central computer system

In effect, the plant computers act like very powerful terminals for the central computer complex, but with complete freedom of action in regard to performing their own work. The main requirement is that the flow of information between all plants be standardized.

Terminal control units

A terminal control unit is the interface between the terminals and the central computer. It takes the load off the computer by organizing and checking messages to and from the terminals (Figures 11 and 12). A "terminal" may, in fact, be another computer.

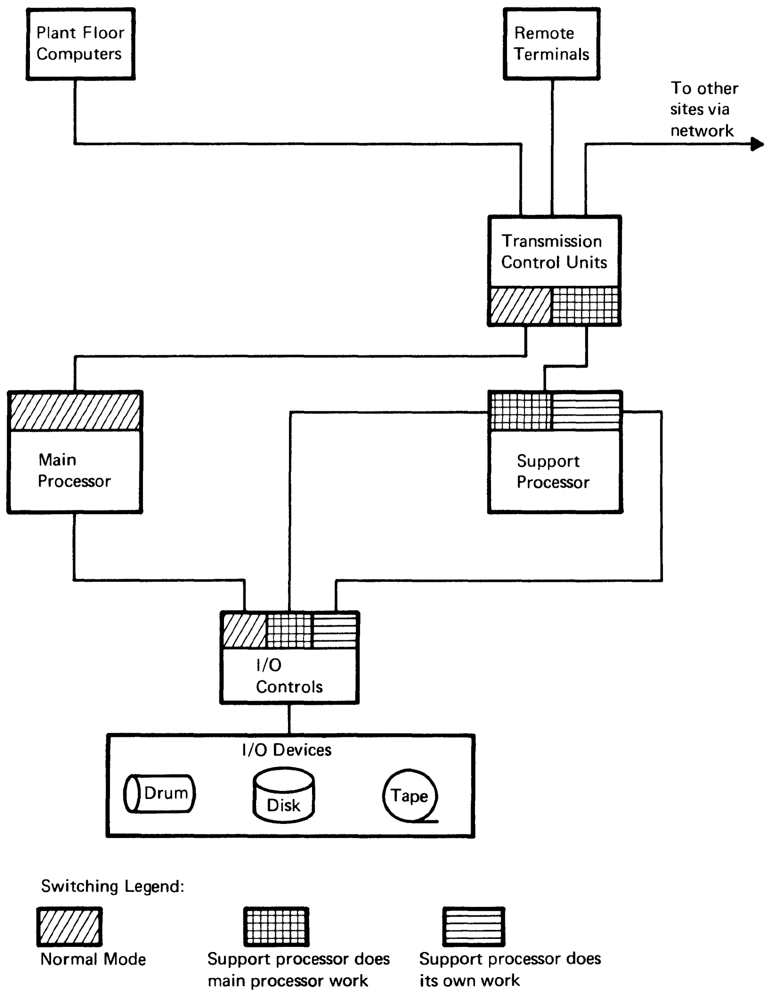

Figure 12. If failure occurs, backup units on one computer can be switched to the other computer in a few minutes

The basic functions of a terminal control unit are to:

- Check whether any terminal is ready to send data (this is called "polling the terminals")
- Check all incoming characters for errors resulting from faulty terminal operation or transmission line problems
- Assemble the transmitted information into a complete message for presentation to the computer
- Check whether a terminal is ready to receive a message
- Transmit the message (as signals) to the terminal and check whether the terminal receives it correctly

Some terminal control units have the ability to:

- Edit incoming messages in order to make sure that all required data has been entered
- Log all incoming messages on magnetic disk storage for backup purposes (in case the main computer is temporarily unavailable)
- Examine incoming messages for priority and immediately direct high-priority messages to the computer complex
- Transfer automatically to other terminals those messages that do not require central computer processing – that is, act as a telephone switchboard between terminals

In systems where the control units perform these functions, costs can be reduced because the central computer is relieved of many minor tasks.

Equipment Backup Requirements

With the installation of communications-based systems, a company places its faith in the continuous functioning of the supporting equipment. If critical portions of the equipment are out of action for too long, disruptions to daily manufacturing operations will result.

The computer system and its associated equipment can, in fact, be regarded as a critical work center through which all operations must pass; and since the computer complex contains many electronic and mechanical components, some failures will occur and must be planned for.

Temporary failures in terminals, communication lines, power supply, and air conditioning must also be anticipated. The possibility of equipment failures should not cause undue concern, because backup facilities can be used until full service is restored. Recovery from failure must, however, be considered an important part of system design.

Equipment duplexing

The most obvious solution to the backup problem is to have a standby duplicate of each component in the system. This is called "complete duplexing". When a component fails, the duplicate is quickly switched in, and full service can be restored within a few minutes. However, this is expensive and not normally necessary in manufacturing companies. It is normally done only for applications such as airline reservation systems, where the whole business depends on the ability of the system to operate 24 hours a day.

When there are several identical components, it is preferable to keep one extra as backup. This applies to tape drives, direct access storage units, terminal control units, etc. If a large number of units are in use (such as terminals), several standby units should be provided.

Duplexing requirements are determined by analyzing the consequences of being without the system for a period of time. Many applications, such as accounting, preventive maintenance, and engineering change control, can survive disruptions in service without serious consequences. The equipment supporting their portion of the system need not be fully duplexed.

In other areas, however, it would be impossible to continue for long without the system. Such areas include manufacturing activity reporting, material requisitioning, job dispatching, and emergency maintenance. Since these areas must have continuous service, their supporting equipment must be duplexed.

System degradation

When some unit of the system fails, the work it normally handles can either be suspended entirely until service is restored or be switched to another unit that performs similar work. In both cases, total system performance is degraded.

Certain noncritical services can, of course, be temporarily suspended without serious consequences. Certain inquiries, for example, or certain requests for briefing reports may be temporarily rejected by the system until full service is restored.

When work is completely suspended because of a system failure, personnel can be assigned to other tasks not dependent on the system. When service is restored, the system absorbs the backlog of work by utilizing surplus capacity during slack periods. In normal operation, however, performance is degraded if processing is delayed, and personnel may have to work overtime to catch up.

switching to other units

The alternative to temporary suspension of work is to switch from the deficient unit to another identical or similar unit not currently in use; normal service can thus be restored almost immediately. Usually, work switched to a unit that already has a regular assignment causes an overload. Such overloads generally result in slower response to requests. During normal operation, for example, the system might acknowledge a report of labor activity in two or three seconds; with overload, this might increase to ten seconds or more.

The acceptance of temporary degradation in certain areas can significantly reduce equipment backup costs. Some units, such as high-speed card punches and printers, may not be duplexed at all; the same applies to units such as magnetic tape drives used for storing historical data.

Equipment provided for backup purposes need not stand idle but can be used for normal service at less than full capacity. This improves normal service while ensuring that capacity will be available in case a similar unit fails.

For backup to the central processing unit a smaller support processor is normally installed. The support processor can be used for batch-oriented applications, with only occasional use for backup. Figure 12 is one example of how duplexing might work in a system performing real-time applications.

The switching of a replacement processing unit may take several minutes. The application areas affected are automatically informed of both the disruption and resumption of service.

Supporting services

Ideally, since failure of the power supply or air conditioning will shut down the system, other sources should be available. Alternative air conditioning can be provided at a degraded level.

Failure of the transmission line serving an area can be remedied by the use of alternative lines to the area (Figure 13). In some cases the terminal can be switched to a line already handling other terminals. Another approach is to run two lines into an area and have alternate terminals running off the separate lines. If one line is not available, the operator can use a nearby terminal on the other line.

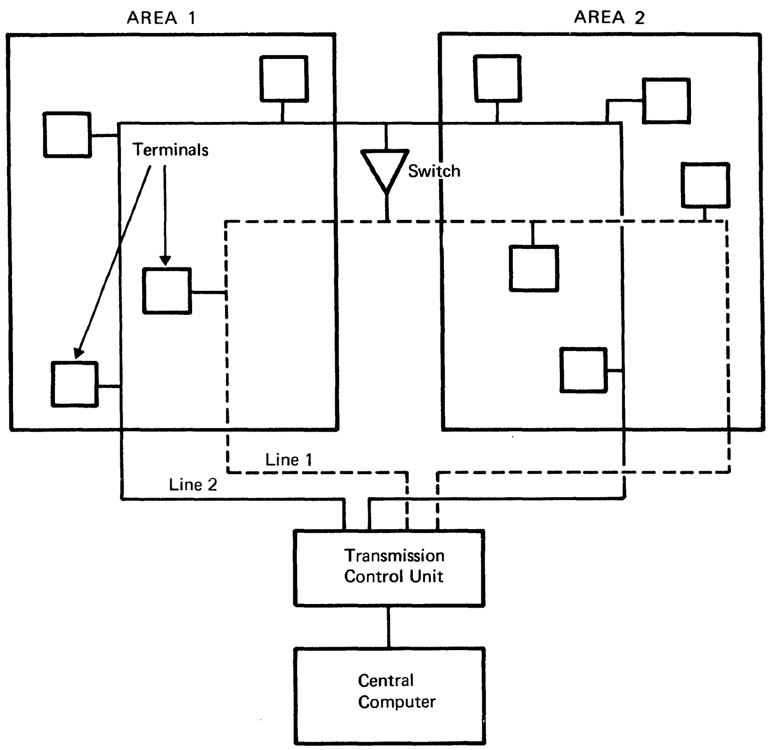

Figure 13. Alternative transmission lines in each area provide protection against line failures

Summary

Real-time processing imposes new and additional requirements on equipment:

Communication terminals can be configurated for any conceivable application. Input terminals provide for variable data entry via keyboards and dials, card and badge readers, and machine counters. Output can be transmitted as a visual display, printed copy, an audio (voice) message, or alarms.

Terminal control units provide a link between terminals and the central computer, and optimize the use of the resources available.

Small computers located on the plant floor can take over some communication functions and offer significant advantages in providing equipment backup. At the same time they can perform direct computer control of manufacturing, materials handling, and testing equipment.

The central computer complex must have more main storage to meet the increased requirements for support programs and to provide the fast response time needed for effective system operation. Additional direct access storage is also necessary because real-time approaches call for most data to be available very quickly.

Equipment backup must be considered an essential part of system design. It can be provided inexpensively if each application program's backup needs are considered independently. Many services can be deferred without serious consequences, while others can survive minor delays until full service is restored. Equipment used to back up critical applications can be utilized for batch-type applications or for improving system performance.

Support Program Requirements

The program requirements for real-time systems are more complex than those for batch-oriented systems. Information flows between units without any assistance from computer operators; much of the operator's function is performed automatically by programming. The system must load its own programs, check its own work, deal with all errors, decide what programs to run first, allocate the necessary computer resources for each program economically, provide security against illegal usage, and keep statistics of its own performance. All this is provided via programming.

Other support programs must be provided to manage the large amount of data required by the system. These programs must provide fast access to all information stored in the system. The organization of data must be versatile enough to meet many different application requirements. Alterations to the data base, required when adding new applications or modifying existing ones, must not cause expensive modifications to all other programs using the data base.

Some of the essential support programs are outlined in this section. These programs are closely interrelated (Figure 14).

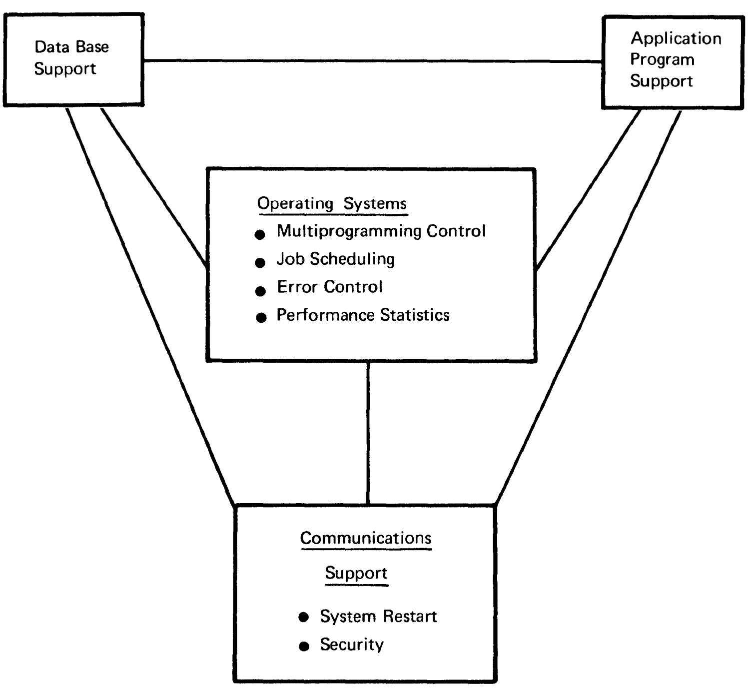

Figure 14. Types of support processors required for communications-based systems

Operating Systems

Operating systems, or "control programs", monitor all computer activities. Their most important functions are:

- Multiprogramming control
- Job scheduling
- Error control
- Maintenance of performance statistics

Multiprogramming control

The main storage device, or central processing unit (CPU), of a modern computer operates so fast that it is impossible to produce mechanical input and output (I/O) devices that can keep pace with processing. Since the CPU depends on the I/O devices for data, it can spend much time waiting for their services. This wasted time can be reduced if several jobs are processed simultaneously. This is called "multiprogramming". Special programs are needed to control such processing.

Figure 15 illustrates a computer that is executing three programs (X, Y, and Z) at the same time. The function of program X is to service a request for a fork lift truck; this program has the highest priority and has just initiated the retrieval of a certain record from a disk file. While X is waiting for the record, program Y (with next highest priority) is activated; Y may also wish to read something from one of the storage devices, or it may perform calculations that do not require any I/O activity. In either case, when the information required by X is available, Y is interrupted and X resumes its processing. If X again issues an I/O instruction, Y resumes at its point of interruption and is again allowed to run until the data for X is available. The sequence of events is illustrated in Figure 16.

Program Z runs only when both programs X and Y are waiting simultaneously for completion of I/O activities. It therefore attempts to use all the spare CPU capacity that cannot be used by programs X and Y.

Under multiprogramming control, the number of jobs being processed simultaneously is dictated by the size of the computer's main memory and the amount of I/O each program requires. In a real-time system several transaction processing programs, together with several batch-oriented programs, are often processed at the same time.

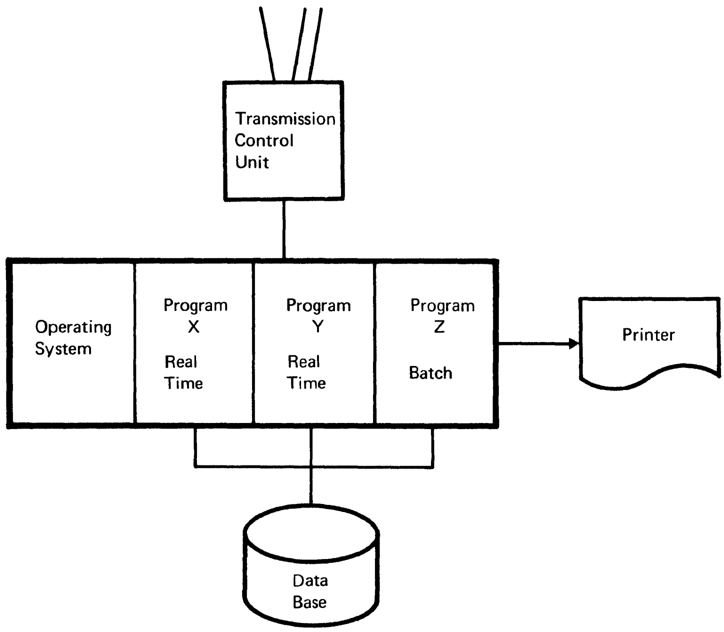

Figure 15. Real-time and batch application programs can be processed by the computer simultaneously

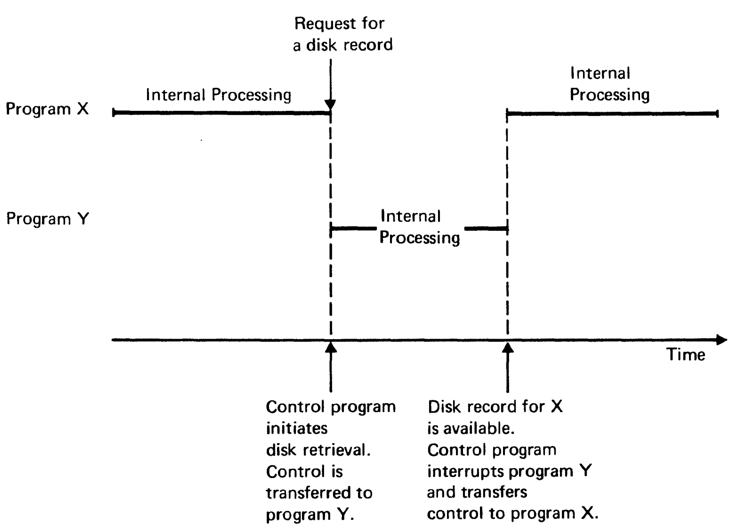

Figure 16. In multiprogramming, the CPU capacity that cannot be utilized by the highest-priority job is made available to lower-priority jobs

Job scheduling

The jobs being processed by the different programs vary considerably in length. Many real-time applications, such as inquiries, are completed in seconds, while other batch-oriented jobs, such as payroll, may take several hours. When a job is complete, the computer resources it has been using become available to other programs. These resources always include portions of the main storage itself as well as input/output devices, such as a transmission control unit, a specific terminal, printer, tape drive, etc. A control program (the "job scheduler") determines how these resources are best used.

During the simultaneous processing of the various jobs, other jobs arrive and request service. The job scheduler program determines the priority of each request, based on rules previously established by the system's designers. When a job is complete, the job scheduler program examines the resource requirements of the highest-priority job waiting to be processed. If the requirements can be met, the job scheduler initiates the job. Any resources not utilized are made available to the next job waiting.

The job scheduler program thus ensures that high-priority jobs are processed first and that computer utilization is efficient.

Error control

Control programs are also required to detect errors in the system. Errors are of two types:

- Equipment errors (when a unit fails to read or write data correctly)
- Application program errors (these can occur if a program has not been fully tested or if data is provided in the wrong format)

equipment error

When the error control program identifies an equipment error, it initiates further attempts to read or write the data. If a further attempt succeeds, the device must have an intermittent failure, and this is logged for later analysis by servicing engineers. Meanwhile processing continues. If the further attempts to read or write should fail, the system itself performs a diagnosis that helps the servicing engineer locate the trouble. The job involved is temporarily suspended.

program error

An error in an application program may cause the program to be terminated, since there can be no automatic correction. The system displays the reason for termination, along with other status information, to help the programmer pinpoint his problem. Alternatively, the program may reject the faulty data and continue processing, depending on options selected by the programmer during program design.

Performance statistics

With multiprogramming it is impossible to account for computer usage simply by recording the time a job takes to run from start to finish. For instance, a low priority job may be in the system for a long time but waiting for other work to be performed. A control program, therefore, keeps a record of how much computer time is actually used by each application program. Such records, printed on request, can serve as a basis for billing the departments using the system.

Statistics regarding utilization of all the computer resources (I/O units, etc.) are also accumulated. These help planners eliminate system bottlenecks, thus improving response time. Facilities with low utilization can be eliminated or shifted to overload areas, thus reducing system costs.

Data base support

The control program features described up to this point are used in both batch-oriented and real-time systems. The control program features now to be discussed apply particularly to real-time systems. They are concerned primarily with restart of the system in case of equipment or program failure; with data base recovery when portions have been lost; and with protection against unauthorized access to the data base.

system restart

In the event of equipment or program failure, the system must be automatically restored to its pre-failure condition. In many conventional systems this presents no problem, either because the original records have not been destroyed or because a complete copy of them is available.

With magnetic tape systems the original tape record is read by the system, in parallel with the recent transactions, and the results are recorded on a previously blank tape. The original records remain the same as before the updating (Figure 17A). The original tape and the transactions are stored for backup in case the new tape is destroyed.

Direct access methods, however, imply "updating in place". The original record is read by the system, updated in main storage, and returned to its original place. The updated record thus overwrites the original (Figure 17B). A batch-oriented job can be resumed after failure by rerunning the transactions against either the original records or an exact copy of them. Copies are made at frequent intervals for this purpose.

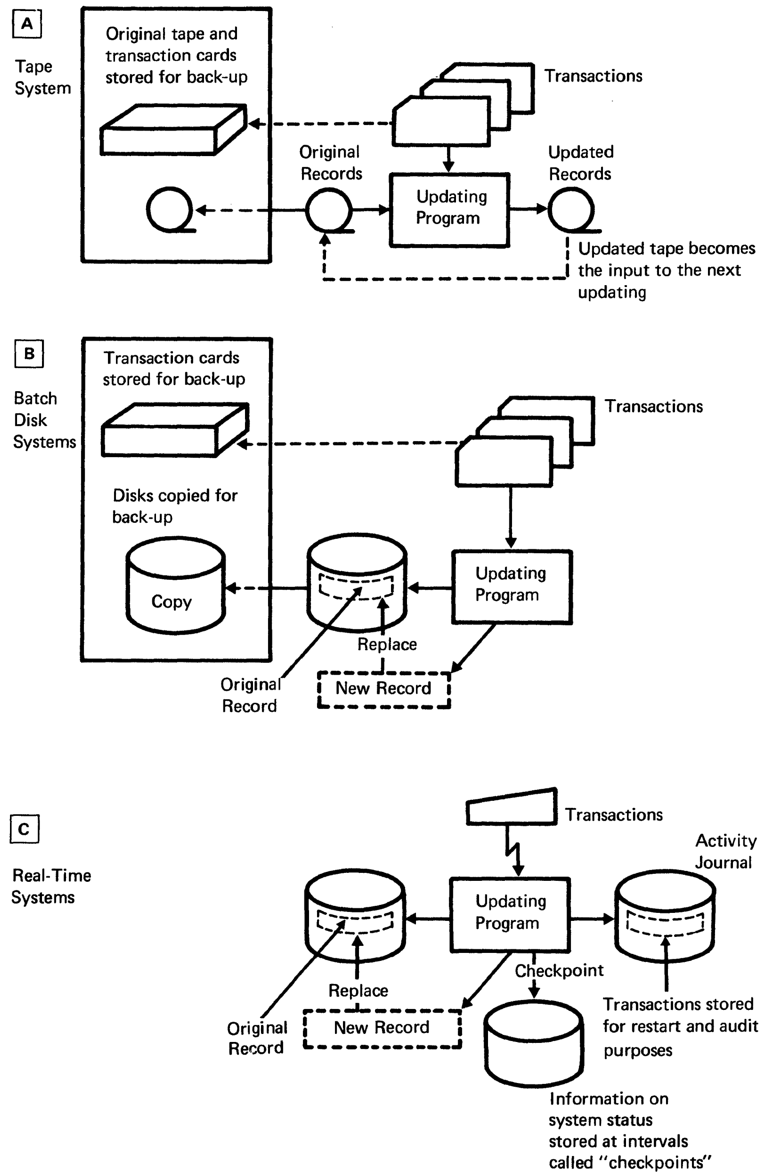

Figure 17. Different techniques are used for restarting the system, depending on the type of processing

In real-time processing, where the original record is destroyed and no copy is available, special techniques are required (Figure 17C). These include:

- Maintaining on an "activity journal" a record of all transactions
- Taking "snapshots" of the system status at regular intervals ("checkpoints")

Restarting the system in case of failure is then possible.

activity journal

The activity transaction journal, or transaction log, is a series of records representing every activity performed by a real-time system (Figure 17C). The journal is updated at various times – in particular, whenever:

- A data transaction is received from a terminal
- A program is scheduled to process the transaction
- A change is made to any data base record (the condition before and after the change is recorded)
- A response is sent to the terminal

The journal thus contains large volumes of data, which are necessary to restore the system in case of failure (see "Data Base Recovery"). Old entries in the journal are discarded after a short retention period. Further details of the activity journal are given in *System Data Base.*

checkpoint

In addition to recording every activity, the system from time to time records information about its own status. At each checkpoint it generates a record showing the status of all its own control programs. Checkpoint recording can be initiated either at equal time intervals (say every ten minutes) or after a certain number of transactions have been processed. The interval between checkpoints should be the same as the maximum acceptable "downtime" interval. The longer the time between checkpoints, the longer the system takes to restore the situation in the event of failure.

restart

Restart is the procedure by which a computer environment is restored to its exact condition before the system failed. The restart routine makes use of the activity journal and the checkpoint records.

The checkpoint record is a "snapshot" of the system's controls at a particular point in time. When there is a failure, the system immediately locates the last recorded checkpoint and uses it to restore the system controls to the status they had just before that time.

All processing performed since that point is then repeated; that is, every activity recorded in the activity journal since the checkpoint is performed again. The system thus retraces its steps.

data base recovery

As mentioned under "Activity Journal", all changes to the data base are recorded. This provides for the recovery of lost records in the event of a breakdown.

Whenever a change is made to a data base record, its details are recorded first on the activity journal. The status of the record both before and after the update is logged. The original data base record can then be reconstructed by returning to the first journal entry (for that record) following the checkpoint; each affected record is thus restored to its "before" status.

Occasionally, a complete backup copy of a data base must be made. Use of this copy together with the activity journal makes it possible to recover from any type of hardware failure. If necessary, a complete data base can be restored by using this facility. The availability of this level of recovery makes it possible to use real-time systems with the same level of confidence as batch-oriented systems.

security

Security measures are necessary for the protection of important information. Unauthorized access to the data base, both from within and outside the company, must be prevented.

The system itself prevents "unauthorized" programs from accessing specified portions of the data base. For example, a program designed to process inventory data will be refused access to payroll data.

Another possible action that must be guarded against is the accessing of private information, such as personnel data. One possibility is to allow access only after the terminal operator has identified himself. Identity is established by insertion of a badge or card in the terminal. The system then matches the identity code against an authorized list.

If an unauthorized operator happens to enter a valid identification, his access can be prevented by either of two additional security measures:

- The type of transaction can be checked for consistency with the location of the terminal. Only specified terminals will be authorized to initiate certain types of transactions. For instance, inquiries into payroll information can be made only from the payroll department terminal.
- The operator can be required to enter a certain "password" along with his request. The password is checked against a list of valid passwords for a particular type of inquiry. If it does not match, access is refused. Passwords can be continually changed as a further precautionary measure.

The combination of operator identification, terminal identification, and password security makes unauthorized access virtually impossible. Examples of the use of security facilities are given in *System Data Base.*

Data Base Support

A system that brings about changes in personnel, objectives, organization, or application techniques meets some resistance. This natural resistance is strengthened by economic considerations. For instance, most system changes require an alteration in how the data is stored in the computer's memory. This change in data organization may take the form of increasing the number of digits allowed for a field of data, adding data not previously carried in memory, and reorganizing the data to allow faster or more economical access.

When such modifications occur, all the programs that use the new information must also be changed. There are usually many programs utilizing each set of data. Therefore, one small change to accommodate a specific program very often results in changing many others. The expense of making such changes is usually regarded as part of "program maintenance". In many companies, the cost of program maintenance may exceed that of developing new applications (Figure 18). In fact, the development of many new applications is constantly deferred because of the complexity and expense of alterations affecting existing computer programs.

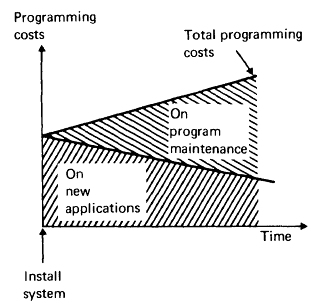

Figure 18. Program maintenance costs may exceed those of developing new applications

One solution to the problem is to extract a separate set of data from the existing set and rearrange it to fit the new approach. The resultant duplication, however, leads to increased data maintenance costs, increased computer storage costs, delays in information processing, and inconsistent sets of files.

The design of the Communications Oriented Production Information and Control System is based on a data base creation and maintenance system that avoids unnecessary duplication of data and permits inexpensive data reorganization. It allows alteration of the data organization without significant changes on programs using the reorganized data files. Since data duplication is unnecessary, data maintenance, storage costs, processing time, and, consequently, the costs of implementing new applications are all reduced.

Data duplication is avoided by cross-referencing related data items when they are held in separate data sets. This allows all associated data to be assembled by application programs "as required". The ability to select data for processing is enhanced when the basic records are arranged in hierarchies, that is, with each record broken into the segments required for each application. Say, for example, that an item record contains separate engineering, inventory, and order data. The segments are broken into smaller units so that individual items of data, such as the details of an individual order, can be processed. Cross-referencing provides the necessary link between the individual order data and the customer order for which the item is required, even though the customer order data is held in a separate data set.

Hierarchical records such as these enable the data to be protected from unauthorized use. For example, the application programs used for instructional purposes may access the skill and training information in an employee record but be unable to read the payroll data in a different segment of the same record.

This flexible data base approach is an essential feature if an integrated system such as COPICS is ever to be a reality. Absence of this approach will result in a gradual reduction in systems application extensions and improvements. Additional detail concerning flexible data organization is presented in *System Data Base.*

Application Program Support

Many of the principles discussed are embodied in existing IBM application programs and program products. These programs are intended to meet the needs of varied companies and usually include options that can be selected by a "customizing" process to suit a company's particular situation. In addition, many programs have "program exits" that allow company programmers to add features and subroutines that apply to unique problems.

The universal applicability of generalized programs usually permits the same basic system to be installed in all plants within a multiplant operation, yet their flexibility allows modification to meet specific plant requirements. This permits effective coordination between plants, and allows the experience gained from the installation of an application in one plant to be used effectively in another. Also, much of the system design, program coding, and documentation is usually available with the programs, thus permitting faster installation and a possible reduction of implementation costs.

Summary

The installation of real-time, large data base oriented systems such as COPICS greatly expands the need for generalized programming support. Much of this support is already available. For example:

- Operating systems (control programs) monitor all computer activities and provide for continuous control of multiprogramming; for the scheduling of the different jobs competing for computer facilities; for the detection and correction of errors; and for the maintenance of performance statistics.
- Additional features of the control programs allow for the restart of the system in the event of equipment or program failure, for data base recovery when portions have been lost, and for the protection of data against unauthorized access.
- Generalized manufacturing application programs and program products help provide solutions to many problems while allowing each company to "tailor" routines to meet individual requirements.

System Design Requirements

Successful implementation of a Communications Oriented Production Information and Control System demands that certain basic requirements be considered during the design of each application. These requirements are general in nature; that is, they are common to all application programs. Careful attention to them significantly improves performance. The following are some of the most important:

- *Action Files.* These are the means by which the system informs an individual that some action is required. Each record in an Action File represents a request for action or a message that some event has happened. The system generates such a request or message whenever an exception condition is detected (and at certain other times). The request or message is directed to the responsible party and can be repeated after a certain time or at fixed intervals.
- *Measurement standards.* "Management by exception" has long been the objective of system design personnel. In principle it relieves management of the chore of reviewing long reports; only the items needing attention are reported. The major obstacle to the success of this method is the lack of measurement standards on which to base the exceptions. Standards are applicable in each of the remaining requirements to be discussed.
- *Response time.* The effectiveness of the system is determined by the quality of service it provides to individuals. One measure of this is how long the system takes to respond to a request.
- *Error detection and control.* The key to error-free terminal use is that all terminal operation should be designed for simplicity. Although the amount of data to be entered should be relatively little, some errors will still occur. Control of error detection is essential if the system is to work efficiently.
- *Management-oriented design.* Different managers require different levels of detail in Action Files or briefing reports. In any one area, the system must be able to provide information at different levels of detail. The first consideration in designing displays and reports is their intended use.
- *Audit and control.* The audit and control requirements of real-time systems are unique. Auditing personnel who are familiar with computers must be consulted during application design in order to satisfy auditing requirements.
- *Data base integrity.* Currently the data supplied to computer systems is less accurate than its users imagine; the effort needed to correct errors and supply the system with "clean" data is almost always underestimated. Inadequate attempts to ensure the accuracy of basic data are often the main cause of problems during application implementation.

Action Files

An Action File consists of a series of records, each of which represents a request for action. The action need not always be immediate. As an example (Figure 19) consider the order release function, which generates requisitions for purchased items. In a Communications Oriented Production Information and Control System, each requisition takes the form of an action message maintained in the computer's memory. These messages, representing open purchase requisitions, are arranged in priority sequence for each buyer, the most important requisitions appearing first. When the buyer is ready to work on another requisition he simply requests a display of the Action File. In effect it is like an "in" tray held on the computer, with the documents sorted into the sequence in which they should be processed.

The buyer follows the procedure for entering a purchase order (see *Chapter 10, Purchasing and Receiving*). After the order is entered, the requisition is removed from the file. If a certain buyer is suddenly overloaded because of an unusual surge in requisitions or because he has to spend a large amount of time on a few unusual situations, his supervisor is notified via Action File. If the backlog for all buyers increases, the manager can also be notified via Action File.

Usually the manager must acknowledge the exception notice by a simple terminal entry. He may also want to enter a code specifying when he wants to be notified again. The code specifies some action, such as:

- Revise the standards creating the exception notice by a specified amount – for example, notify again if the load reaches 12 days' backlog instead of 10.
- Do not notify unless the same condition exists in five days.
- Keep notifying until the condition is corrected.

The Action File concept is an essential ingredient of a real-time management control system. It provides several significant advantages:

- Through his ability to change limits, a manager can dictate the amount of information he wishes to receive and the degree of control he wishes to exercise.
- The system is assured that the responsible person has been notified of the exception: the message is automatically routed, the receiver must usually acknowledge receipt of the message, and he must normally identify himself to the system via a special code or a plastic identification card.

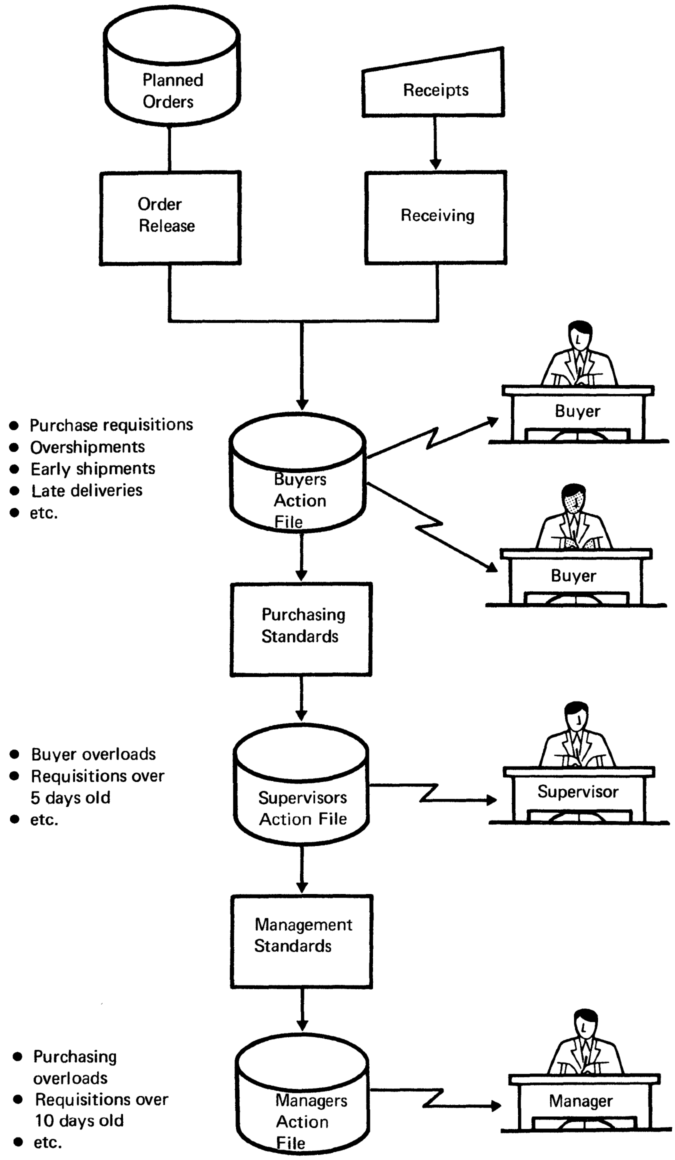

Figure 19. The level of management informed by an Action File is determined by the importance of the exception and by the time lag before it is corrected

- The file acts as an inventory of required actions. It places action notices in the sequence specified by the section creating the notification. This ensures that the important items are handled first – in other words, that the important or late customer orders are filled first, the important receipts are inspected first, the important shop orders are worked on first, etc.
- It ensures that people are notified in the proper sequence. This allows sufficient time for lower-level managers to react before top-level managers are informed.

Real-time processing, effective standards, and fast communication of exception conditions provide early warning of potentially costly situations. The earlier the warning, the better the chance of avoiding costly corrective procedures. The normal type of historical reports, pointing out mistakes of days or weeks ago, is the most expensive form of exception reporting.

Measurement Standards

Performance cannot be measured without some standard. Therefore, business has developed standards both to measure performance and to provide incentive. Common standards include those for direct production labor, sales quotas, budgets, etc.

If management is to avoid being buried by voluminous reports (the condition with many of today's systems), standards development must be extended into other areas. The lack of effective standards is the reason why, in today's business systems, the monitoring and control phases are the weakest point.

COPICS concepts assist in the development of measurement standards. This is essential, because the large number of standards required precludes the possibility of establishing and maintaining them manually. Assume, for example, that a plant manager was to be informed when any of the following eleven conditions at each of his 400 work centers were excessive, compared with the current level of production activity:

- Rework hours
- Indirect labor (four types)
- Off-standard labor (two types)
- Scrap
- Work center downtime
- Work center idle time
- Size of work backlog

The manager or his staff would have to establish 11 x 400 or 4,400 standards. Maintenance costs for these would be prohibitive, because the dynamics of the shop floor would force their constant alteration.

In most cases, system-developed standards will be averages, or weighted averages, of past performance. For example, averages or indices could be based on the previous month's performance, a weighted average of the last six months' performance, last year's cumulative performance to date, or last year's performance for the same period. Standards need not, however, be based solely on history. Under the COPICS concept, extensive detailed plans can be developed based on the master production schedule, which is an estimate of future production activity. These detailed plans can also be used as standards – for example, actual overtime versus planned overtime, actual late orders versus expected late orders, etc.

To initiate exception notification, the plant manager must specify the percentage deviation from standard in which he is interested (for example, a 10% increase in rework, a 2% increase in scrap, etc.). The percentage is easy to enter into the system. If the manager is receiving too many notices, he simply raises the percentage; if he wants to establish tighter control, he lowers the average.

The system can also calculate trends for certain important items and thereby predict when a standard will be exceeded.

Computer-developed standards can be self-maintaining. That is, as business conditions change, the standards change in proportion. The technique of monitoring the change, called "exponential smoothing", is detailed in *Chapter 3, Forecasting.*

Response Time

When the terminal operator enters information, he expects a fast answer, or a confirmation that the data has been accepted by the system. The interval between entry of the last character of information and the typing or display of the first character of the reply is known as the response time (Figure 20).

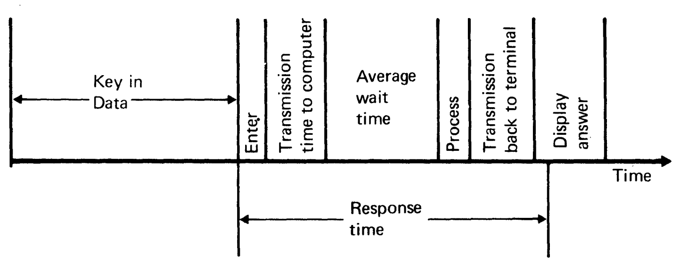

Figure 20. System response time is the length of time the operator is inactive at the terminal

The allowable response time for different types of transaction can vary from a few milliseconds (for instance, if a computer-controlled machine must be shut down because of dangerous emergency conditions) to several hours (for certain types of noncritical briefing reports), and it must be carefully determined. For most transactions originating from the shop floor (such as production activity reporting), the maximum acceptable time is a few seconds; if the response is slower, the operator's concentration is broken.

Slow response also wastes valuable operator time. On the other hand, unnecessarily fast response usually means unnecessary equipment cost. Figure 21 shows the relationship between response time and the cost of the communications system. As the response time required approaches one or two seconds, the cost increases dramatically.

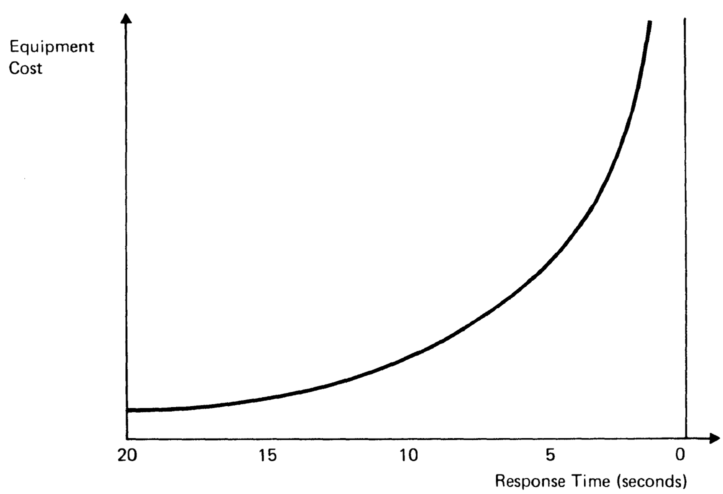

Figure 21. Fast system response must be balanced against equipment cost

Response time for a particular type of transaction is not constant, but varies with the current transaction load on the system. Incoming transactions normally arrive at random time intervals. Suppose, for instance, the system must respond to ten messages per second on the average; the interval between any two consecutive arrivals is not a constant one-tenth of a second, but is highly variable. When several messages arrive in quick succession, the later ones must "queue" for service. Usually, the major part of response time is the time that the message is waiting in queue.

Some inquiries or transaction requests must be serviced immediately, while others require much computer processing time. If transactions are made during a period when few other requests are received, or the other requests require little processing time, response is correspondingly faster.

To resolve contentions for the use of the system's resources (particularly for main storage), a priority is assigned to each transaction. The system allocates the resources of the computer to the highest-priority job in the "queue" of contending jobs. The priority code thus has a major effect on the average response time for a particular transaction type. For a transaction indicating machine breakdown the priority may be higher than for a transaction updating shop order status.

The load on the system, especially during peak periods, must be constantly checked to determine whether it allows the required response times to be achieved. The response time required is the major factor in determining the cost of a communications system. Care must be taken to establish response times that are compatible with both operator requirements and cost conditions.

Error Detection and Control

Data entered into the system is immediately made available to all areas requiring it. It is therefore important that all data be checked for accuracy *at the time it is entered.*

Effective error control is vital to the integrity of the system. Unless all levels of management are convinced of its accuracy, the system will be partially or totally abandoned in favor of "informal" systems. Old methods will be reinstated, and the computer system will become an expensive status symbol.

Because terminals are relatively new tools, they often provoke negative reactions among personnel. Operators cling to the old methods instead of ensuring the success of the new. From the start, therefore, detection of errors is extremely important. The system also gains new respect if it is seen to provide valid results.

In system design, then, heavy emphasis must be placed on both the detection of and the speedy recovery from data errors. Speed is necessary because the rejection of a faulty transaction means that the data base is not entirely up to date; this can lead to errors in other areas.

Error detection

There are many methods for detecting transaction errors, most of which are currently employed in batch-oriented systems. They include:

- Incorporation of a self-checking digit into an identification number (such as a shop order or purchase order number). The self-checking digit, generated from the original digits and appended to them, becomes a permanent part of the identification. An example of this approach ("modulus 11") is shown in Figure 22. If any digit is incorrectly transmitted, the self-checking digit is found to be inconsistent with the others and the transmission is rejected.

Generation of Self-Checking Digit

Shop order number	1	7	6	4	2	
Multipliers	6	5	4	3	2	
Product	6	35	24	12	4	
Sum of products	6+	35 +	24 +	12 +	4	= 81
Multiple of 11 which is just greater than this						= 88
difference = Self-Checking Digit						= 7

The self-checking digit is appended to the shop order number, which becomes 176427

Whenever a transmission is made, all six digits are entered, and the arithmetic is repeated. Almost all errors will cause a different self-checking digit to be calculated.

Figure 22. The use of self-checking digits can lead to detection of many numerical errors

- The use of "reasonableness" filters for quantitative data. For example, an unusually high quantity reported at one operation can be detected and the transaction rejected as a result. Reasonableness standards must be established for each class of data. In most cases the system determines them automatically from a statistical analysis of the quantities involved.
- Establishment of tolerance standards for certain data. For example, up to ±5% inaccuracy in counting procedures may be allowed for quantities reported during production and receiving.
- Application of message format editing to every transaction. This verifies that all the required data fields (for the type of transaction concerned) have been entered. Additional checks ensure that the correct number of digits are entered for each field.

- Checking most data entries against data previously recorded. For instance, when a shop order is reported as complete, either a record for it must already exist in the system or the data entry must be wrong. Similarly, the quantity reported must be consistent with that reported for the previous operation.

Error control

When an error is detected during data entry, the system sends back a message so notifying the operator.

Normally the first step is to ask the operator to correct and reenter the field of data that was in error (he need not reenter the whole transaction). Most errors are corrected at second entry. After two consecutive errors in the same transaction, the system automatically requests that assistance be given to the terminal operator. In an environment with close supervision (such as customer order entry), automatic assistance requests are probably unnecessary. On the plant floor, however, terminal transactions are not supervised, and system-produced requests for assistance must be transmitted to a responsible person, such as a foreman or supervisor, via a high-priority Action File. Each request indicates the type of error detected. The terminal operator is informed via the terminal regarding what further action he is to take. He may be told to wait for assistance or to proceed to his next assigned job.

If, as often happens, the foreman is unavailable, notification of the incorrect transaction is sent to a Transaction Control Center. (Depending on the size of the plant and the variety of transactions, there may be several such centers.) The center is responsible for instructing the foreman (or employee) how to correct the error. Communication can be by phone. This method centralizes responsibility for control and usually leads to faster and more accurate error correction. Many errors may result from the failure of other areas to transmit their transactions when necessary. The control center is in the best position to correct errors resulting from such situations (Figure 23).

Management-Oriented Design

The design of the system must be based on the needs of the managers using it. Efficient computer usage is necessary but of secondary importance. Unfortunately, when system design is left to the computer technician (and management does not participate), efficient computer usage often becomes the primary target.

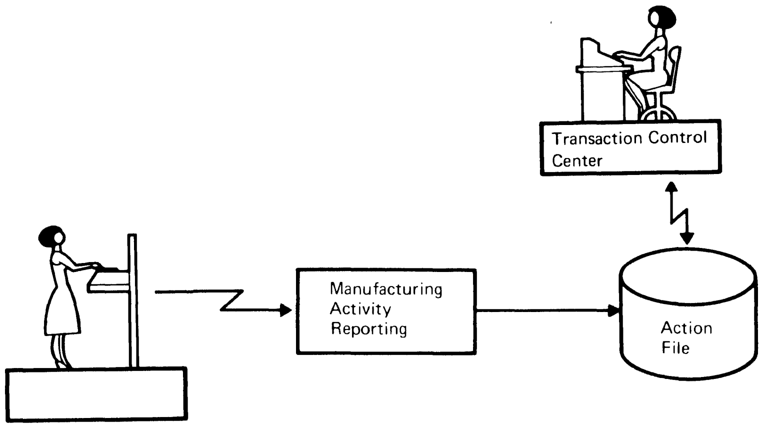

Figure 23. The Transaction Control Center is notified of repetitive errors for investigation and correction

In deciding the type of information required, the following are some of the criteria.

Level of management

The type of information provided by the system varies with the responsibility level of its users. Figure 24 illustrates how the interest level varies with the management level.

For effective presentation, levels of detail should not be mixed. For instance, the plant manager should not have to search through a report for departmental totals hidden among detail lines. The totals should be displayed separately. The plant manager can request any further details as required.

Simplified presentation

The extensive use of numeric codes and incomprehensible abbreviations should be avoided, especially on briefing reports that are not used every day. A manager will ignore a report he cannot understand, no matter how important the data. Full words should therefore be substituted for codes and abbreviations whenever possible. Figure 25 is an example of a bad presentation.

TOP MANAGEMENT	MIDDLE MANAGEMENT	OPERATING MANAGEMENT
PLANT	DEPARTMENT	MACHINE
PRODUCT GROUPS	INDIVIDUAL PRODUCTS	PART NUMBER
CUSTOMER TYPE	CUSTOMER	ORDER NUMBER

Figure 24. The level of detail required varies with the level of management

	INQUIRY 002			PRODUCT 11850				PUMPING UNIT	
......	LOT	-	SIZES	....	.....	STOCK	....		ISSUES..
PRICE	MIN	MAX	MULT	LT	SS	O - H	AV	PER	Y-T-D
25.00	20	-	10	9	30	93	63	35	620
DATE	ACTN	PRIM	SEC	GROSS	ORD	ALOC	ORD	REL	AV
331	ORDR						1002	200	263
331	REQT	20		25					238
332	REQT		55	55	A601				183
336	ALOC				A183	100			83
336	REQT			5					78
338	REQT		45	45	A602				33
341	ORDR						1007	200	233
341	REQT			5					228
343	ALOC				A187	50			178
344	REQT		70	70	A605				108

Figure 25. An example of a computer report not designed for easy comprehension, and therefore ineffective

In analyzing a briefing display, the manager, or his subordinates, should not have to perform mental arithmetic; the system can do it much more cheaply, and accurately.

When it is felt that printed output, rather than just a display of the data, is necessary in response to a simple request, it can be provided.

Ease of use

Terminals must be easy to use, since they play a key role in transmitting and receiving information. The system should assist the operator in the entry of the required data.

For example, suppose the priority of a customer's order is to be altered to speed delivery. The operator enters a two-digit transaction code (see Figure 26, 1st entry). The system responds with the display indicated (1st response) and requests a five-digit customer order number. This is entered (2nd entry). The system responds (2nd response) with a confirmation of the order number and details of the order; it also requests the new priority number. The operator enters the digit required (3rd entry). The system responds with a confirmation of the change (3rd response).

All terminal entries and inquiries are guided in this way; the technique reduces training time and data entry errors.

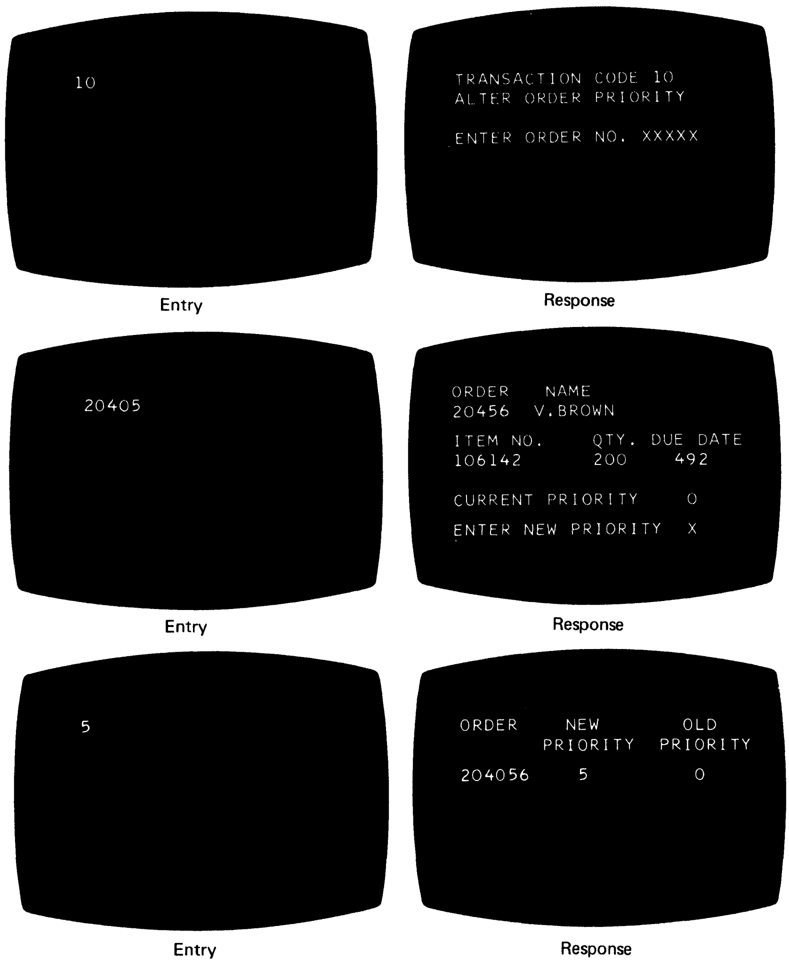

Figure 26. The design of terminal transaction procedures should allow the system to "talk the operator through" the transaction

Managers may or may not want to have direct access to terminals. The more complex entries can be made by experienced operators, but many managers may prefer to make their own requests to the system and conduct rapid "conversations" with it.

Audit and Control

Real-time systems impose special requirements on audit and control functions. For example, the system does not require detailed transaction lists of material movements, material receipts, and labor activity for operating purposes. If large volumes are involved, the maintenance of such lists for subsequent audit is an unnecessary and expensive chore.

Consequently the audit trail should be made an integral part of system design. This means that auditors should participate in system design. Lists, where necessary, can be retained on magnetic tape, simplifying storage requirements and making possible automatic computer retrieval of specific transactions on demand.

To ensure that all transactions have been correctly carried out, the auditor can design test transactions and dummy master records to test all aspects of system activity. These transactions can be periodically entered into the system to make sure that processing is still performed as originally specified.

The auditor may also employ the technique of randomly tagging selected transactions entering the system. This special tag instructs the transaction processing system to prepare a detailed listing of all affected data records. The listing shows the status of the records before and after the transaction is processed. This provides a complete trace of all activity on a random basis.

New approaches to audit and control can be developed to meet any real-time situation. Many will be superior to the techniques established to control manual systems. Auditors familiar with computers can help system design personnel create effective audit and control techniques that fully utilize the power of the computer.

Data Base Integrity

Existing data is rarely as accurate as it is assumed to be. Usually, the effort needed to create and maintain the new data required for the system is also underestimated. Establishment of the basic data utilized by the system should start well before it will be required. This means that for some period of time, two sets of data may have to be maintained – one for the old system, and one for the new system.

System design and application conversion logistics must consider the overload on the departments that supply and maintain this information. Special temporary procedures may have to be installed to help with the overload.

Extreme care must be taken to ensure that the data base is created and maintained correctly. Failure in this area is one of the major causes of system implementation upsets. Once the new system is installed, however, the amount of clerical labor needed to create new records and maintain existing records is usually considerably less than for the old system.

People who are familiar with the existing procedures and who will be responsible for using the new system should be involved in the conversion. Problems can thus be sorted out as they arise and people will have an interest in inputting good data.

Summary

During detailed system design there are many important considerations that are common to every application program. These include the establishment of valid standards that serve as a basis for management by exception by relieving management of the tedium of reviewing voluminous reports in order to pinpoint problems. Via Action Files, the system can automatically notify responsible personnel of possible problems and action needed. The managers and employees responsible for taking the required action have complete control over when re-notification is to be generated. Higher-level management can be notified if problem conditions in lower-level Action Files are not cleared up in time.

Response time is one of the most important considerations in effective system design. If response to terminal data entries and requests is too slow, personnel will criticize and possibly abandon the system; if it is too fast, excessive equipment costs will result.

Effective error detection and control is necessary if personnel are to have faith in the system. This may call for the creation of a Transaction Control Center to ensure that all corrections are quickly made.

Terminal transactions must be designed with the terminal user in mind. This means that readable formats must be used instead of a series of unintelligible abbreviations and codes. The system must guide the terminal operator through each transaction; it must also provide output in a form that does not require further manual processing.

The audit and control techniques established must be different from those traditionally used to control many systems. This can best be accomplished if auditors familiar with computer techniques participate in system design.

The integrity and accuracy of the data base must be ensured if the system is to succeed. Temporary procedures may have to be set up to help certain departments create the necessary new data while maintaining the old system.

Failure to perform effectively in any of these areas will seriously jeopardize the success of the system.

Conversion Considerations

This section deals primarily with the sequence and speed of application conversion. When considering the overall approach to implementing a system as big as COPICS, management is usually concerned with five general questions:

- Is it desirable or necessary to run an application in a batch environment before proceeding to real-time processing?
- How candid should one be in informing personnel of pending changes?
- Does real-time processing imply that computer processing must be centralized?
- With all the possibilities for system improvement, in what application area should implementation start?
- How long will it take to install the system?

Of course, the exact answer to each of these questions depends on individual company situations. The following are some general comments that apply to most companies.

Batch before Real Time?

The techniques of data entry, audit and control, error control, etc., for real time are entirely different from those for batch. In addition, the advantages of up-to-date information open up entirely new system approaches. Therefore, an initial conversion to batch processing usually means wasted effort. The use of batch techniques in a real-time environment is as difficult to justify as the use of existing manual techniques in a batch computer environment. Neither takes advantage of the computer. A completely new approach and system design will replace that of the batch procedure when real-time processing is installed.

Of course, many of the applications described in the COPICS chapters are batch-oriented. Where real-time processing is indicated, however, it can profitably be employed from the beginning without using batch processing first. Considerable savings in time and effort will result.

There may, however, be reasons why this cannot be done – for example:

- Programs for real-time processing may not be available for a particular application – batch programs can profitably be used in the interim period.

- The current volume or frequency of transactions may not justify the investment in a real-time environment.

In such cases the application has to be initially installed as a batch application.

A company with no experience in implementing online applications should first consider converting an existing batch application. Once experience has been gained, however, there is little need to establish batch procedures first. Such practice, in fact, can be costly and time-consuming because of the retraining necessary.

Full Disclosure of System Impact?

Companies that have withheld information concerning system impact on employees have generally regretted the results.

System implementation often means altering job assignments for many employees, because the system takes over many functions and the revised procedures create new requirements. Employees must be told of such system impact as soon as it is known. Their cooperation is needed before implementation in order to obtain accurate data for effective system design and conversion. Apprehension over system impact may cause them to be uncooperative and to undermine the system.

Cooperation after conversion is equally important. Without enthusiasm for the new approach, employees may keep finding reasons why "it will never work" rather than solutions to inevitable minor problems.

Centralize Computer Processing?

Every multiplant operation must face the question of whether to centralize data processing.

Before the time of high-speed data transmission, companies were tending to decentralize in order to give local management the "authority to act fast". Centralization then implied an automatic and sometimes serious delay. Now, however, much of the delay can be removed, and centralization can therefore be economically implemented. This is not necessarily to say that it is desirable, only possible.

Experience has shown that when an application is to be installed in many plants, it is best to install it completely in one plant first. Implementation is simplified if the computer is located at the site where the application is being installed.

The decision as to what to centralize can be based on equipment and line costs. Centralization may lower computer equipment costs but significantly increase communication line rental costs. Long communication lines, because of cost, may also have to operate at lower speeds; this degrades system response time. Whether or not applications should be centralized, therefore, depends on balancing equipment cost and response time.

The installation of essentially the same application procedures at all plant locations permits easy implementation of policy decisions concerning centralization. Work can be moved from one location to another without serious disruption. Small plants can be started on central systems and then converted to their own local computer when data volumes justify the transfer.

Where to Start?

Implementation of the Communications Oriented Production Information and Control System can start with almost any application area (Figure 27). It should begin where the largest problems and biggest savings potential exist. If an effective materials control system has already been implemented, the initial application areas may be MANUFACTURING ACTIVITY PLANNING, PLANT MONITORING, or PURCHASING.

If major problems exist in all application areas, a suggested sequence is:

- FORECASTING and MASTER PRODUCTION SCHEDULE PLANNING
- INVENTORY MANAGEMENT – first of finished goods, and then of component parts
- ORDER RELEASE
- PLANT MONITORING – at least the part that provides the latest status on shop orders
- CAPACITY REQUIREMENTS PLANNING and ORDER RELEASE PLANNING (part of MANUFACTURING ACTIVITY PLANNING)
- OPERATION SEQUENCING
- PURCHASING, RECEIVING, and STORES CONTROL

The procedures presented in *Chapter 1, Engineering and Production Data Control* will be implemented as each application area requires them. For example, item data, bills of material, and engineering change control will have to be implemented at the same time as MATERIAL REQUIREMENTS PLANNING for component parts and raw materials; manufacturing routings and facilities data will have to be established at the same time as MANUFACTURING ACTIVITY PLANNING.

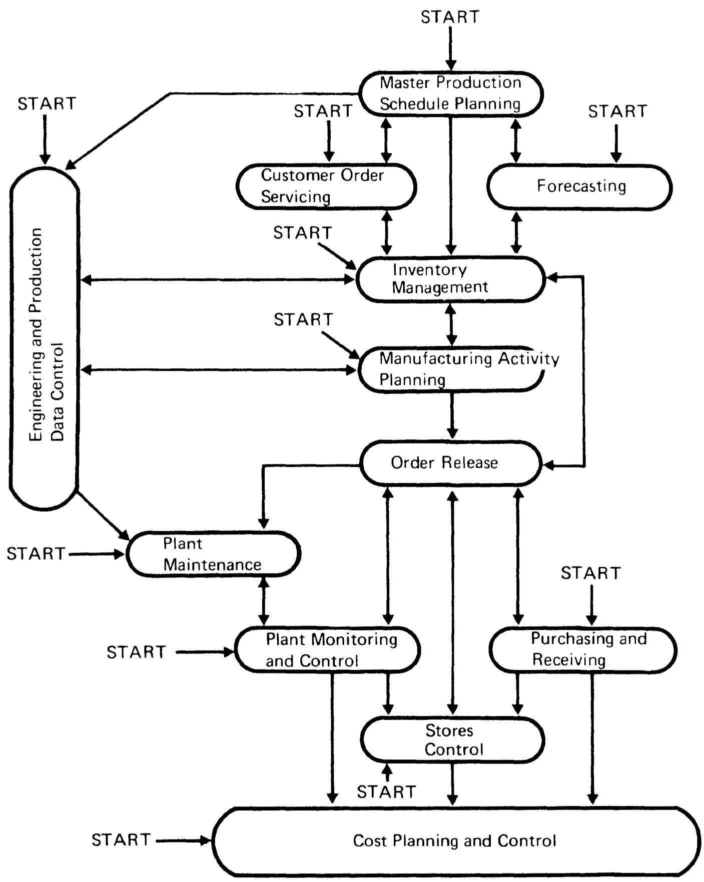

Figure 27. Implementation can start in almost any application area

To provide an effective tool for Design and Production Engineering, ENGINEERING AND PRODUCTION DATA CONTROL can be established initially for use by these departments and then expanded into the other areas.

CUSTOMER ORDER SERVICING can be installed at any time, since it is less dependent on the other systems.

The COST PLANNING AND CONTROL applications outlined can be installed at any time. However, most of those outlined are dependent on the data collected in PLANT MONITORING AND CONTROL and must, therefore, be deferred until the latter is installed.

PLANT MAINTENANCE uses many of the techniques employed by the regular production systems. As these systems are installed, they should be expanded to handle the special requirements of Plant Maintenance. Those portions of PLANT MAINTENANCE not connected with other systems, such as preventive maintenance interval planning and control, can be implemented at any time.

The purpose of this sequence is first to reduce the upsets due to ineffective forecasting and master production schedule planning, and then to establish tight control over component parts in order to reduce the incidence of shortages and expediting. ORDER RELEASE sets up the basic data needed for PLANT MONITORING AND CONTROL. The latter system provides the status information needed for effective manufacturing activity planning.

It must be emphasized that the sequence should depend on the magnitude of the problems in each area. Some companies may choose to start with MANUFACTURING ACTIVITY PLANNING or PURCHASING AND RECEIVING. If the overall system design is kept in mind and the interfaces between portions of the system are well defined, it is possible to start in any application area without causing wasted effort or lost time.

How Long to Install?

Implementing a system as big as COPICS is no short-term affair. In most companies it will take several years. Although some companies may attempt simultaneous conversion of several application areas, implementation costs will keep many others from attempting too much at one time.

It is fair to say that complete implementation of a business communication system is never accomplished, for no sooner is a system installed than new techniques and new equipment are introduced that open up profitable new approaches to problems. The system implementation plan must be revised and re-prioritized to reflect these changes. In this sense, a five-year implementation plan should never be more than a few months old. It should be constantly updated and extended to include the latest problem approaches and changes in the company's business.

The development and improvement of business communication systems should therefore be considered a permanent and important part of business planning.

Glossary

COPICS Glossary of Terms

This glossary contains a definition of each major term used in the COPICS publications. It provides a reference for the meaning of both new and established terms.

In most instances, a term is also defined the first time it is used in its related chapter. It is not usually redefined, however, when used in other chapters. For example, "capacity requirements planning" is defined in *Chapter 6, Manufacturing Activity Planning,* but not in other chapters.

■ ■ ■

accounting ratio – An indication of the relationship between costs and activity levels on the basis of current operating methods – for example, cost per man employed, per square foot occupied, per unit sold, or per unit purchased.

Action File – A data processing technique used to forward requests for human decision or intervention to the correct individual(s). Within COPICS, an Action File is maintained for each functional area and for each management level. Requests for actions that cannot be processed automatically by the system are stored in the appropriate file. Information is usually extracted from the file in priority sequence, first highlighting the most critical situations. If no decision or action occurs within a given time, the next higher level of management can be automatically notified. Also see "Trigger File" for automatically initiated actions.

ADE – See "Automated Design Engineering".

advanced release – See "forced release".

allocate – To reserve a quantity or amount of a given resource for a particular customer order, shop order, or maintenance work order. The allocation can be either firm or tentative. The term is generally used in regard to inventory. See also "allocation, firm" and "allocation, preliminary".

allocation, firm – An allocation that has been made to an order (normally used in regard to inventory). The order can be a shop order, work order, or customer order. The allocated quantity is reserved for that order until it is physically removed from stock. In the instance of a shop order, the allocated quantity is reserved for that order between release time (when requisitions are issued) and the time of actual withdrawal from stores.

allocation, preliminary – An allocation made during requirements planning. It is only planned and is not firm. For items with pegged requirements (see "pegging requirements"), it enables the system to simulate how requirements may be covered by available inventory, released orders, planned orders, or safety stock. Preliminary allocation builds the networks of orders used in Manufacturing Activity Planning.

alternate operation – See "routing, alternate".

alternate routing – See "routing, alternate".

alternate work center – See "work center, alternate".

asset ledger – A ledger (usually maintained by the finance function) that records basic information for each fixed asset (machine, truck, building, etc.). It includes such information as asset number, original cost, depreciation method, depreciation period, book value, capitalized revenue, machine-hour rate (cost rate), etc. In COPICS it is part of the facility record.

associated resource – See "resource, associated".

attendance reporting – A procedure for recording the time of arrival and departure, as well as overtime worked, for employees. The information is used to calculate an employee's hours worked and, subsequently, his pay. Entry of arrival times via a terminal allows for quick, automatic assessment of the ratio of planned to available manpower for a work center or department and allows the foreman to make assignments quickly.

audio response – A voice response assembled from recorded words stored in the computer system. When work station terminals are in the form of a telephone handset with pushbutton capability, data is keyed into the pushbuttons and transmitted to the computer, which "orally" acknowledges the data entry and guides the operator in entering additional information. Various dispatching instructions may be given in this way, if desired.

audit trail – Stored information that allows the history of an account, item record, order, etc., to be traced. It may provide, for example, information concerning transactions, status as of a given date, or other desired information. The more recent information may be stored online in a historical section of the files for retrieval by terminal.

automated assembly – Assembly by means of operations performed automatically by machines. Products so assembled include light bulbs, circuit boards, etc. A computer system can monitor the production and quality levels of the assembly operations.

Automated Design Engineering (ADE) – Automatic creation of bills of material, either partially or totally, for assemblies, finished products, etc. Design specifications for a desired item are input to a computer and processed according to the design logic (stored in the computer) for the item's family. Output is the bill of material for an item having those specifications. It is frequently used for variations and options of a standard product when the product must be adapted to specific customer requirements. Examples of such products are elevators, pumps, boilers, and air conditioning units.

Automated Manufacturing Planning – Automatic creation of routing data, either partially or totally, for items in a given family. Routings are produced directly from design specifications, using the logic developed for the item's family and stored in a computer.

automated warehouse – A warehouse that employs automatic handling equipment to move materials from a receiving area to a bin or from a bin to an outgoing area. Instructions to the automatic handling equipment may be given either by an operator in the warehouse, or, if greater efficiency is desired, directly by a computer.

available – Not yet allocated (firm). An available item may be on hand or in the process of being manufactured.

backward scheduling – A scheduling technique that starts from the due date of an order and determines the start date for each operation by successively calculating and subtracting the various lead time allowances. If the start date for some operations falls into the past, the system attempts to hold the schedule by squeezing the normal lead time allowances. See also "forward scheduling".

bill of material – A list of components for an end product or assembly, or of raw materials for a part. A bill of material basically identifies parent item, either for a single assembly level (level-by-level bill of materials) or through all levels, from end item to lowest-level components. It may include additional data like engineering change level, shrinkage factor (loss of components when building the assembly), time offset between the start data of a present order and the required date of the component, etc.

Bills of material may be organized to provide "where-used" information – for example, the names of the parent items in which a given component is used, and the quantity.

Bills of material may be organized from either a design point of view (functional assemblies) or a production point of view (physical assemblies), or they may be combined.

bill of material, field installation items – A bill of material for item(s) that can be fitted only when a product is being installed in a customer location. Item examples include electrical connections, piping, etc. These items should be shown as part of the product's bill of material and coded to indicate their relationship.

bill of material, formula – A list of materials called for in a formula. Some products (paints, dyes, chemicals, pharmaceuticals, rubber, plastics, etc.) specified by a formula can readily be stored and processed in a manner similar to that of a bill of material. Intermediate mixtures or products may be considered as assembly levels. In such cases the stored information is called a formula bill of material.

bill of material, packaging – A list of the packaging requirements for a component, assembly, product, etc. Packaging may be considered as an additional level of assembly; items may be packed by the unit, in various size boxes, in a particular size box within a carton, special packs, etc. This information can be easily held and maintained in the product definition data base and requirements generated in the same manner as for any other component.

bill of material, service parts – A bill for parts or assemblies, used to service or repair an end product or assembly. A bill of this type becomes necessary when a part or assembly being sold as a replacement requires some parts such as joints or gaskets which normally are components of the next higher level assembly in the end item's production bill of material. These service parts may be included in the end product's bill along with a code specifying that they must be considered only from a service parts point of view. This creates a form of a combined bill of material.

bill of material organized by variant – Bill of material in which items common to all assemblies of a family are collected into a main bill of material and items that change with a specific variant are collected into a separate bill. This reduces file size significantly when the number of variants would generate enormous numbers of bills of material if other file organization techniques were used. Using this technique, the system can develop a complete bill of material, including variants, as required.

bin – A storage location identified by a number which is its geographical address. Normally, only one type of item is stored in a bin at a given time. Examples of bins are: one cell in a bank of shelving, one storage vat, one location in a large field (as for castings and forgings), one position in a rack, an area marked out on the plant floor, etc.

bin card – A form physically attached to bin, having columns for recording receipts, issues, and remaining balance. Bin cards are not usually required in an online stores system.

bin management – Control of storage facilities by relating bins to the items they can contain and assigning the most suitable bin to a new receipt.

bin selection – A technique or procedure for selecting a bin in which to store an item. Before an item can be stored in the warehouse, questions concerning a storage location must be answered – e.g.: Must different lots of this item be segregated? Is there other stock of this item? If so, where? Is there capacity for this receipt in that location? If a new bin is needed, what bin type should be used? Which bin of this type is nearest to existing stock of the item or is most accessible?

blanket order – A purchase order that calls for a specified amount or quantity (usually a large quantity) to be delivered over a specified length of time (three months, six months, one year, etc.). This helps to obtain a lower price by giving a supplier an opportunity to buy and plan more efficiently. Confirming orders or instructions for partial shipment of the item(s) involved are provided as the item is needed.

blanket routing – See "routing, blanket".

bottleneck – A facility, function, department, etc., that impedes production – for example, a machine or work center where jobs arrive faster than they leave. Also, shortage of a move facility of a given type or capacity.

branch warehouse – See "field or branch warehouse".

breakdown maintenance – See "maintenance, breakdown".

capacity, daily – Quantity of work, measured in hours, that a work center can perform in a 24-hour day, including adjustments for unproductive work breaks such as personal time and for work center efficiency.

capacity, normal – Anticipated number of hours to be worked by a work center each time period. This can vary across the planning horizon.

capacity, maximum – The maximum number of working hours available at a work center in a given time period. This can vary across the planning horizon.

capacity requirements – See "requirements, capacity".

capacity requirements planning – See "requirements planning, capacity".

Carry Level – An inventory quantity of an item that the inventory control function strives to maintain. This approach is common for some slow-moving items like maintenance parts for plant facilities, or service parts.

catalog search – Identification of an item ordered by description or function, without item number. This is usually done by a clerk, looking in a sales catalog. It can also be performed by a computer with keywords entered to describe the product. This generates a display containing item number and description of all items corresponding to the keywords.

combined bills of material – See "bill of material".

common setup – A setup that is common to several operations on one part or several parts. Grouping these operations in a sequence saves setup time and cost.

composite routing – See "routing, composite".

computer program – A series of instructions or statements, in a form acceptable to a computer, prepared in order to achieve a certain result.

conditional order – A customer order that has to be confirmed, perhaps because it has been placed via telephone. The order is recorded as conditional and available inventory or future production may be allocated to it. If the order is not confirmed within a given number of days, it is canceled; any allocations are reversed and the items are made available.

configuration control – Ensuring that the product being built and shipped corresponds to the product ordered and designed – that is, that the correct features, customer options, and engineering changes have been incorporated. These are major problems in industries where there is a long manufacturing lead time for the product and where changes are constantly being made from initial design through delivery of the product.

consigned components – Components or materials supplied to a subcontractor for incorporation in an assembly or item he supplies.

consumable tool – See "tool, consumable".

contention for tools – Simultaneous need for an individual tool by two or more shop orders. This contention is usually resolved in Operation Sequencing, which considers the priority and urgency of jobs.

continuous net change – See "net change, continuous".

control center – The point where decisions are made for job dispatching and to which the shop floor feedback is addressed. In a centralized shop floor control system, the key to successful operation is rapid communication between the shop and the control center, through the use of terminals.

cost account codes – Codes indicating the account to which an expense should be charged. In a computer-based system, the cost account codes can be as detailed as necessary for effective cost control.

cost center – A cost area of responsibility to which expenses are charged. The criteria in defining cost centers are that the cost be significant and that the area of responsibility be clearly defined.

critical items – Items considered in Material Requirements Planning that have a lead time longer than the normal materials planning horizon, or items whose scarcity may impose a limit on production. Usually, the materials planning horizon should be as long as the accumulated lead time for all levels of product manufacture and assembly. Sometimes, however, because of competitive pressures or for other valid reasons, management may decide to quote finished product lead times that do not include the unusually long lead times required to obtain certain components or raw materials – for example, special types of steel or castings. In this instance, the items to be produced from these materials are "critical items" and other than normal techniques must be used for their control.

critical resource – See "resource, critical".

critical work center – See "work center, critical".

custom-bonded items – inventory – Imported components to be incorporated into finished products being exported. Custom duty is frequently not paid on these components, and special documentation and control are required for consignment with the finished product.

customer delivery instructions – Instructions given for the delivery of goods to be shipped – delivery address, shipping method (truck, rail, air freight, etc.), days and hours when deliveries are accepted, maximum weight and size of packages, special packing instructions, and so on.

customer order servicing – The handling of customer orders, from initial order or request for quotation to shipment of finished product. Objective is rapid and accurate entry of orders into a control system that will ensure on-time delivery and improved response to customer information requirements.

custom manufacture – Production according to a customer's particular specifications.

cycle counting – A continuous physical inventory count at or near specified intervals of time. Depending on an item's classification, the frequency of its count can be weekly, monthly, annually, etc., or, if desired, it can be based on prespecified management instructions concerning item inventory value, usage, etc. The count is normally performed by a regular team of inventory checkers and does not require stores to stop inventory transactions.

day length – Factor expressing the number of working hours in a day. It may vary by work center.

defect analysis and control – The examining of an item's or supplier's inspection history with the aim of instituting closer quality control wherever required.

demand – The actual demand (as opposed to actual shipments or sales) for an item or product for a specified period of time. Because of shortages and delays customer shipments may be an unreliable indication of actual customer demand. Therefore, in order to forecast demand and thereby generate requirements, accurate demand data is necessary.

demand, dependent – Demand that depends on the planned orders for a higher level assembly or product. It is computed from a production plan for finished products by using the bills of materials for those products. The means of determining dependent demand differs from the determination of independent demand in that dependent demand is arrived at through the use of the production plan of higher level assemblies or products. Independent demand does not rely on that relationship for its development. See also "demand, independent".

demand, independent – Demand for products, assemblies, or materials, which is not directly related to the demand for another item at a higher assembly level. Examples of such demand are: customer demand for end items and service parts, miscellaneous demand. See also "demand, dependent".

demand, miscellaneous – Demand for an item originating from sources such as product test and development engineering. When significant, these requirements may be statistically planned and ordered.

development shop order – Shop order for items needed for experimental devices or prototypes.

deviation, forecast – Difference between a forecast and actual demand. Also called "forecast error".

direct labor cost variance – Variance or difference between the standard direct labor cost and the actual direct labor cost. It is generally used to determine the total effect of variances on plant profits and the part of the total that is attributable to individual managers or cost centers. In this way, performance can be monitored and guidance provided. The cause of variances, such as changes in the labor efficiency, in lot sizes, or in the manufacturing process, should be determined.

Direct Machine Control – Use of a computer for online monitoring and control of the manufacturing, testing, or material moving operations. See also "Direct Numerical Control", "high bay warehousing", "machinery control", "production counting", and "production monitoring".

direct material price variance – Difference between the standard cost of the material for a given item or order and the actual material cost.

Direct Numerical Control (DNC) – A means of controlling a machine tool or other facility directly by a computer. This is in lieu of the computer creating a punched tape that is then read by a machine tool's controller to initiate the movements and functions of the machine. With DNC, tape reading errors, the possible use of outdated tapes, tape libraries, etc., are substantially reduced or eliminated. Also, because instructions are fed to the machine tools and feedback is sent to the computer, the status of the tool is always available via inquiry. See also "machinery control".

distributed – Decentralized

downtime – Time during which a machine is stopped by a breakdown.

earliest start date – Earliest date an operation or order can start. Restricted by current date, material availability, and management-specified "maximum advance".

econometric forecast models – Forecast models aimed at establishing a relationship with external economic indicators, and also with internal factors such as price changes, type and amount of advertising, salesman's compensation, etc.

economic indicator – An indicator external to the business but closely associated with the demand for a product. For example, carpet demand may be projected from housing starts.

efficiency factor – See "work center efficiency".

elements of interoperation time – See "interoperation time".

embodiment loan item – Component, material, or special equipment provided by the customer to be used on or incorporated into his order.

emergency maintenance – See "maintenance, breakdown".

end item – See "item, end".

engineering and production data control – Creating, organizing, maintaining, and retrieving the basic engineering records within a company. The data processing methods used for these records may also be used advantageously for other records in most manufacturing companies.

engineering change – A change to an item or an assembly, for reasons of safety, technical improvement, cost reduction, new manufacturing process, standardization, easier maintenance, change in customer demand, etc. Engineering changes result from demands from various departments; they may be studied simultaneously by several engineering groups under different aspects, and their consequences may affect a diversity of data, products, and resources.

engineering change control – Estimating the cost and the effect of an engineering change, the parts to be obsoleted or reworked, the loads on production facilities and vendors, etc. It also implies the ability to maintain consistency of data: related changes on parent and component items, item data, product structures, requirements, drawings, routings, tools, jigs and fixtures, gauges, test instructions, parts catalogs, maintenance instructions, commercial documentation, etc.

engineering change coordinator – An individual with final responsibility for planning, checking, and implementing an engineering change, regardless of what help a computer gives in this respect.

engineering change history – See "product history data".

engineering drawing issue level – A level or issue number of a drawing that tells the last engineering change or change level incorporated.

estimated time – Estimate of the time required for an operation. It is usually the standard time for the operation and is expressed as time for one piece, or time for 100 pieces, etc. It is used as a basis for capacity requirements planning and cost estimating.

expense budget – Departmental budget, itemized by type of expense, normally based on the sales or production activity expected, and approved by management.

explosion, bill of material – A procedure to determine how many of each of the items listed in a bill of material will be required to produce a given quantity of the item or product represented by the bill. For example, if 500 of product A are required and A is composed of two Bs, three Cs, one D, and four Es, the explosion will determine that 1000 Bs, 1500 Cs, 500 Ds, and 2000 Es are needed. If either B, C, D, or E is an assembly, its calculated quantity will then be used in the same way to "explode" its bill of material and determine the quantities needed of its components. See also "bill of material".

external priority – See "priority, external".

facility record – A record containing data describing production facilities, such as work centers, tools, machine tools, and storage locations. The record includes such data as facility description, location, capacity, efficiency, planned loads, maintenance specifications, and cost information.

feedback data – Data describing the result of a previous decision or action and used to determine actual status and deviation from a plan, so as to initiate corrective action.

field or branch warehouse – A decentralized warehouse or distribution center in a distribution network. When field warehouses are used, Customer Order Servicing can take advantage of centralized inventory management to improve customer service and reduce inventory. Orders accepted at the field warehouse may be transmitted to the central location, which determines the field warehouse most suitable for delivery and transmits shipping instructions to it.

file – A collection of related records treated as a unit. For example, one line of a bill of material may form a record, a complete bill may form a series of records, and all the bills of material may form a file.

finished products inventory – See "inventory, finished products".

finite loading – See "load leveling".

floor stock – Inventory issued to the plant in excess of immediate requirements – for example, a complete reel of wire when the requirement is only for 50 feet, and small parts that are used repeatedly.

forced release – Release of a shop order for which one or more required components are not available. Order Release checks the availability of all components of an order to be released. If a shortage is discovered, release is normally delayed while the inventory administrator is notified. When production can start without the missing component(s), the inventory administrator may decide to force release of the order.

forecast data conditioning – Checking to determine whether there is sufficient demand data for a forecast, whether data is present for all periods, and whether there are periods of very unusual demand that should be suppressed.

forecasting, extrinsic – A forecast model that associates historical demand data with the values of indicators external to the business, such as the average bank interest rate on loans. The use of regression analysis reveals the indicator and demand, and converts the forecast of the indicator to a forecast demand for the item or group.

forecasting, intrinsic – A forecast model based on the historical demand data of an item or group. It uses statistical methods and the technique called regresssion analysis and extrapolates the data into the future.

forecasting, horizon – The time span in the future over which the forecast of demand extends. The length of the time span is normally determined by product lead time but it may be extended to permit long-range company profit planning.

forecast judgment modification – Alteration of the forecast to reflect new or unusual factors such as a sales contest, a new competitor, market expansion, etc., that may affect demand.

forecast model – A mathematical formula suitable for forecasting the demand, usage, etc., of an item or group of items. There are two types of models: linear (horizontal, linear trend) and nonlinear (exponential, logarithmic, sinusoidal, etc.). The system chooses the model type best fitting the available data.

forward scheduling – A scheduling technique that starts from an order start date and determines a finish date of that order by adding operation duration times and interoperation times. See also "backward scheduling".

full pegging – See "pegging requirements".

gateway work center – See "work center, gateway".

gross requirements – See "requirements, gross".

growth curves – Curves that show the forecast demand during the introduction and initial acceptance of a product, and that can be represented by a mathematical equation.

hand tool – See "tool".

high bay warehousing – A method of automated storage in which cells or pallet racks extend vertically beyond the range of normal handling equipment such as fork lift trucks. Movement of materials into and from these racks is done by stacker cranes remotely directed by an operator or, if greater efficiency is desired, by a computer.

idle time – The time during which a machine or operator is nonproductive because of lack of work.

independent demand – See "demand, independent".

infinite loading – See "requirements planning, capacity".

interoperation time – Elapsed time between the completion of one operation and the start of the next operation on the same job. It may be subdivided into postoperation time (e.g. cleaning or local inspection), wait time (waiting for transport facilities), queue time (waiting for available labor and machine), and preparation time (any preparatory work not otherwise described).

inventory, finished products – Inventories of finished products intended to be shipped to customers. Service parts are considered as finished products, though they may also be used as components of other finished products.

inventory, obsolete parts – Parts waiting for disposition and salvage. They may be stored in separate locations and be subject to special control techniques.

inventory, physical – The counting of inventory items to determine their exact stock status. Despite tight control on transaction reporting, editing, and inventory updating, errors may occur through the reporting of inaccurate quantities, wrong entry of item number or stock location, unauthorized issue or pilferage, etc. Physical counting is used to locate and correct these errors. See also "cycle counting".

inventory, production material – Inventories of all raw materials, parts, and assemblies that are purchased, fabricated, or assembled in the effort to produce finished products.

inventory, semifinished component – Assemblies and components that are stored in a semifinished state. This can help reduce setup costs and lead times. For control purposes, these items usually carry separate part numbers.

inventory, service parts – Inventories for service parts. While often carried in a separate location, these can also be consolidated with the inventories of production materials. Requirements for service parts are usually estimated statistically and must be added to requirements for production generated by material requirements planning.

inventory accounting – The administrative, or bookkeeping, aspect of inventory management. It covers the entry, auditing, control, and processing of inventory transactions, including transaction history and audit trails, as well as the gathering of transaction data from remote locations, physical control over stock, and inventory counting procedures. See also "inventory management".

inventory administrator – An employee responsible for certain sections of the inventory. For instance, he revises all orders for "A" items or a certain product line. He can approve an unusually large request for product test for certain parts, coordinate the exact time that an engineering change has to be made, etc. Sometimes called "inventory analyzer" or "parts controller".

inventory control – See "inventory planning and control".

inventory management – Management of the inventories, with the primary objectives of determining (1) items that should be ordered, and in what quantity, (2) the timing of order release, and order due dates, and (3) changes in the quantity called for and the rescheduling of orders already planned. Its two broad areas are inventory accounting, which is the administrative aspect, and inventory planning and control, which consists of planning procedures and techniques that lead to inventory order action. See also "inventory accounting" and "requirements planning, material".

inventory planning and control – Planning procedures and techniques that lead to inventory order action. See also "inventory management".

item – Any unique manufactured or purchased part or assembly, that is, end product, assembly, subassembly, component, or raw material.

item, end – End product, or the highest level of assembly shown by the bill of material.

item data – Data describing products, the component parts and raw materials from which they are made, the bill of material, and the routing indicating the manufacturing process. Included is data such as item number, description, unit cost, lead time to manufacture or purchase, and other relatively fixed descriptive information. Also included is information subject to frequent change: on-hand inventory balance, future requirements, and planned orders.

item storage characteristics – Description of an item's physical properties, by which receipts are assigned to a proper storage bin. Characteristics may be weight, dimensions, fragility, need for special environment, pilferage probability, frequency of movement in and out, shelf life, etc.

job assignment – Assignment of an employee to a machine or team, or of a job to a machine, employee, or team. Assignment, made by the foreman, is based on information supplied by the computer through a terminal.

job dispatching – Instructions given to an employee concerning the next job he is to perform.

key machine – A machine that is critical to the plant operation – for example, a unique machine working close to its maximum capacity.

latest start date – The latest date by which an operation or order can be started in order to meet the due date of the order.

lead time – Time elapsed between the moment an order is placed and the moment the goods are available. See also "lead time, production" and "lead time, purchase".

lead time, manufacturing – The elapsed time for a manufactured order, between order release and the availability of the items in the warehouse.

lead time, production – An estimate of the time required in the shop from order release to availability in stores.

lead time, purchase – Lead time for a purchase order, from the moment a purchase requisition is issued to the buyer, up to the moment the received goods are inspected and made available in stores.

lead time, safety – A time buffer intended to compensate for a possible delivery delay. For example, if an order is going to be needed on the 15th of the month, and it is for a critical item, it may be scheduled for receipt on the 1st, thus allowing a safety lead time of 14 calendar days or 10 workdays. For items whose demand is not regularly distributed, but bulky (a quantity of 200 to 500 is required as a batch every two or three months), safety lead time can frequently provide reasonable safety at a cost lower than that of carrying safety stock of the item. Safety lead time is normally used for purchased items.

lead time offset – product structure – The time difference between the due date of a parent order and the due date of its components. It is normally equal to the lead time of the parent order. However, if some components are needed at a later time than the parent order start date, this may be specified in the product structure data.

learning curve – A curve that shows an expected progressive improvement in performance. Learning curves are usually employed when new products or operators are introduced. Based on experience and historical data, they can be applied automatically by the computer to adjust the standard time over the life of the curve, for production planning and payment calculations.

life curve – A curve that reflects the forecasts for the various phases of demand for a product – namely, introduction acceptance, full production, and phasing out. It represents the probable distribution of the total demand (for an item) over a period of time.

load leveling – The procedure of moving operations or orders in such a manner as to smooth, in accordance with the capacity, manpower and machine requirements over part or all of the planning horizon.

load profile – A report in numerical and graphical form that shows the projected overloads and underloads on each work center.

location code – Code given to each work center to indicate its geographic location within the plant.

lumpy demand – An erratic demand pattern in which the difference between minimum and maximum is relatively large.

machine control – See "machinery control" and "Direct Numerical Control".

machine utilization – See "utilization of machines".

machinery control – There are two broad categories of machinery control: Machine Control (MC) and Direct Numerical Control (DNC). MC, the broader of the two, consists of initiating by a computer the sequence of functions that are built into a machine tool – for example, the movement of a stacker crane in a high-bay warehouse, or the operations on a transfer line. DNC is the application of computers to directly control the operation of a machine tool.

maintenance, breakdown – Emergency maintenance, including diagnosis of the problem and repair of a machine or facility after a malfunction has occurred.

maintenance, emergency – See "maintenance, breakdown".

maintenance, planned repair – Maintenance work subject to advanced planning techniques but not likely to be repeated in the near future, or, if repeated, not likely to be performed in the same manner. An example is the repair of a roof.

maintenance, preventive – See "maintenance, repetitive".

maintenance, repetitive – Maintenance work to be repeated at intervals. It includes both minor operations like lubrication and inspection, and major jobs like the overhaul of a press. Also called "preventive maintenance" (PM).

manufacturing lead time – See "lead time, manufacturing".

master production schedule – A statement of net requirements for a particular end item, specified by date and quantity. Such schedules reflect management policy as well as actual or forecast customer demands.

material requirements planning – See "requirements planning, material".

materials management – See "inventory management".

maximum capacity – See "capacity, maximum".

move request – Request to the materials handling department for personnel to move material from one plant location to another.

move time standards – Standards based on estimates of (1) the average time spent by materials waiting for materials handling equipment in a given work center and (2) the time it takes to move from a specific location to another (transportation time). This may be a significant part of the manufacturing lead time and is used for planning purposes.

net change – A technique in which a plan is updated by each transaction, addition or subtraction, as it occurs, as an alternative to periodic regeneration of the complete plan. See also "net change, continuous" and "requirements planning, net change".

net change, continuous – A technique that allows continuous, online application implementation. It is normally thought of as a Material Requirements Planning method. It is used with a so-called "transaction driven" system that accepts all transactions, including schedule changes, in a random input stream. Only a continuous net change system can actually be completely up to date at all times. See also "requirements planning, net change".

net change requirements planning – See "requirements planning, net change".

net requirements – See "requirements, net".

network – A network of orders that describes how lower-level components and subassembly orders are related to the building of an end product order.

network priority – See "priority, network".

non-exploded items – Dependent items with regular demand that are planned as if they were independent, through statistical forecasts. This reduces computing time in material requirements planning. A code in the structure record suspends the normal calculation.

normal capacity – See "capacity, normal".

Numerical Control data – Numerically controlled machine tool instructions that are held as part of the routing data or as separate instructions in the computer system. They can be produced in a form readable by the control unit of the machine tool when the shop order for the item is being produced, or the machine tool can be directly connected to the computer which feeds it instructions and receives feedback data. This latter method is called Direct Numerical Control (DNC).

obsolete parts inventory – See "inventory, obsolete parts".

open order – See "released order".

operation overlap – See "overlapping".

order identity lot sizing – Purchase or production of components for a specific customer order independently of identical components used for other orders. In this case, the component requirements must be identified by the customer order (full pegging) and the grouping of requirements (lot sizing) can be made only inside the quantity required for the customer order.

order point technique – One of two basic approaches to planning and controlling inventories of independent demand items; it utilizes data on the historical behavior of an inventory item and considers the demand for each item to be independent of the demand for other items. The other basic approach, material requirements planning, can perform the same functions as order point while at the same time planning the requirements for dependent demand items, thus offering the advantage of a single planning system. Order Point looks at the past, whereas Requirements Planning looks toward the future. Also called "statistical inventory control". See also "order point technique, time-phased" and "requirements planning, material".

order point technique, time-phased – A technique in which order point records are in time-phased format, using the same materials planning horizon as the dependent demand items. Used to combine requirements of end products and service parts. This means that the forecast for service parts is extended beyond the next point of replenishment.

order priority – See "priority, order".

order release – The connection between the planning and implementation phases. Its function is to change the status of an order from "planned" to "released".

order servicing – See "customer order servicing".

overlapping – The "sending ahead" of part of a shop order (to the next operation) before the entire order has been processed at the current operation.

overload tolerance – The possible overload in a work center, above the normal capacity. It is one way to express the difference between normal and maximum capacity. May be expressed either as a percentage or in hours.

overshipment – Delivery from a supplier in excess of the quantity ordered.

parallel running – Simultaneous performance of an operation for a job on several machines.

parts controller – See "inventory administrator".

parts list – See "bill of material".

parts program – The instructions needed to process a given part on a numerically controlled machine tool. They may be in the form of punched tape, or may be stored online in a computer and either punched out at the time the shop order is written or transmitted to a shop floor computer for Direct Numerical Control.

parts programmer – An individual who writes and checks out the instructions needed to process a given part on a numerically controlled machine tool.

pegging requirements – Keeping track of the relationship between requirements for specific end item orders and the requirements that they generate for lower-level components. Depending on the industry, pegging may have to be made in different ways: (1) for an individual end item in production on customer order, (2) for a batch of end items in repetitive production, (3) identifying directly the end item for which each component is due (full pegging), or (4) identifying directly the next assembly level only, with the possibility to trace the requirement origin level by level thorough all levels (single-level pegging). Pegging connects all materials into networks that allow a kind of critical path scheduling – earliest dates, latest dates, etc. It allows a simulation of component allocation in order to plan the production of assemblies and end items.

permanent tool – See "tool, permanent".

physical inventory – See "inventory, physical".

picking – Taking materials out of their bins to satisfy requisitions. See "picking list".

picking list – A list of items to be picked in stores. For the sake of efficiency, it groups together a number of requisitions or orders on the basis of factors supplied by management, such as order priority, maximum number of picks per list, multiple orders for the same item, geographical sequence, etc.

planned order – A shop order or purchase order automatically planned to cover net requirements. It does not represent a firm commitment and can be automatically modified for changing conditions until approved or modified by the responsible authority or released.

planned order schedule – Statement of orders planned for future release. Extending over the planning horizon, it is developed and maintained for each inventory item by Material Requirements Planning. After it is converted to machine loads and summarized by work center by time period, it yields an accurate picture of productive capacity requirements.

planned repair maintenance – See "maintenance, planned repair".

planning capacity – See "requirements planning, capacity".

planning horizon – The time span covered by the different planning systems. It can vary from several years in Master Production Schedule Planning to a few days in Operation Sequencing.

plant floor computer – A small computer located in the plant to handle sensor-based applications and shop floor control. Usually, each computer operates in a limited area of the shop and, in addition, may be connected to the centralized processing system.

postoperation time – The time interval during which the parts are delayed after the completion of an operation. It is expressed as a percentage of setup plus run time. Possible causes of delay include cooling and inspection.

postponed release – Postponement of the release of a shop order because of unavailability of one or more components. Normally, this allows the other components to be used by other orders. However, the inventory administrator can decide to reserve or allocate the available components pending receipt of the short components, if he so desires.

preparation time – Time during which the part is delayed prior to processing, expressed as a percentage of the operation duration (setup plus run). The delay is caused by some preparatory operation not in the routing, such as cleaning, heating, marking out, etc.

preventive maintenance – See "maintenance, repetitive".

priority, external – A value provided by management to reflect the importance of a customer order. For example, a penalty clause for late delivery of an order would result in a high external priority. This priority is used as a factor in calculating the order priority of associated shop orders.

priority, network – Priority value associated with the network containing an individual order. It is used in order release planning to determine the sequence in which networks should be loaded onto work centers. See also "network".

priority, order – A value calculated by the system and used to rank an order relative to all others. Among the major factors affecting order priority are order due date, number of days delay expected, slack between earliest and latest start date, and external priority.

product group – A group of products having common classification criteria. Design engineering may classify items by function, size, shape, or material in order to retrieve all items having common characteristics, when required for a specific design purpose. This avoids duplications of design, routings, items, stock accounting, etc. The sales department may classify items by product groups according to potential users, function, size, etc.

product history data – Data allowing the configuration of any completed item to be retrieved. Depending on the industry, the history file may vary from a complete copy of the bill of material of each individual item built, to an engineering change file specifying the serial number of the end items from which they were applied.

production counting – The automatic counting, by computer, of parts as they are produced by a machine. It is done through a sensing device on the machine which, in some cases, also allows the computer to stop the machine when the desired quantity is reached.

production lead time – See "lead time, production".

production material inventory – See "inventory, production material".

production monitoring – Checking the status and progress of production activities. This may be done through workers and terminals or by direct machine control. In the latter case, machines are connected to the computer, which directly monitors the status and performance. See also "Direct Machine Control".

product mix – The distribution of the various items in a production plan.

product structure history data – Data that allows the retrieval of the structure of an item built in the past. See also "product history data".

product support – Service and maintenance of delivered products. This generally implies knowledge of the exact structure of each item delivered, in terms of components and engineering change levels, how it was built, and possibly how it has been modified since delivery. This, in turn, implies maintaining and retrieving the product history in terms of bills of material and engineering change levels. The problem is complicated by the fact that some industries, such as aerospace, rarely make two identical versions of the same product.

profile of loads – See "load profile".

program – See "computer program".

purchase cost commitment control – A simulation which considers the standard cost and the payment conditions of planned and released purchase orders so as to plan cash requirements.

purchase lead time – See "lead time, purchase".

quality control – The function of establishing and maintaining specified quality levels for products.

quotation – A proposal made to deliver an item at a given price and within a specified lead time.

raw materials and purchased parts routing – See "routing, raw materials and purchased parts".

realistic start date – The data an operation or order should be started, considering availability of material, available capacity, and order priority. It is assigned by Order Release Planning.

receiving – Identification and validation of a receipt and routing of the material through counting and inspection to stores or direct to the area requiring it.

reclamation control – Department determining the disposition of all items rejected during receiving inspection.

reclamation shop order – A shop order that specifies the rework that is necessary for off-standard items received from suppliers or from the shop floor.

regression analysis – A technique used in forecasting that fits, through data points, a line minimizing the distance from the points to the line. This line is called "regression line".

released order – An order that has been transmitted to the supplier or the shop floor. It is considered as an addition to available inventory on the date of expected delivery. Requirements planning does not automatically modify released orders but highlights any change in the due date or quantity. Authorized people may then modify a released order, if it is still feasible.

repetitive maintenance – See "maintenance, repetitive".

requirements, capacity – The workload that will be imposed on a facility if a given amount or quantity of a product(s) is to be produced. Normally, it is generated by Capacity Requirements Planning from the materials plan developed by Material Requirements Planning. See also "requirements planning, capacity".

requirements, gross – Total requirements for a component, raw material, subassembly, or assembly, before available inventory and released orders are subtracted.

requirements, net – Total requirements for a component, raw material, subassembly, or assembly, after available inventory and released orders are subtracted. See also "requirements, net".

requirements planning, capacity – A determination and projection of the workload (capacity requirements) by time period for each work center, department, plant, etc. It enables management to determine future bottlenecks, underloads, critical areas, etc. It is one of the main functions of Manufacturing Activity Planning.

requirements planning, material – One of two basic approaches to planning and controlling inventories. It has two main logical steps: (1) a simulation of future inventory position computed from present inventory and planned or known future issues and receipts, and (2) explosion of requirements into lower-level requirements through bills of material. These two steps are repeated at each assembly level, starting with end items. In this way, requirements and shop and purchase orders for lower-level components are computed from the end item requirements. The other basic approach, order point technique, looks at the past and uses historical data, while requirements planning looks to the present or the future by using actual or forecast orders to generate requirements.

requirements planning, net change – A method of changing a material requirements plan, whereby the previous plan is retained and modified only with current changes. Computation is limited to the consequences of changes, as opposed to a complete requirements regeneration. See "requirements regeneration".

requirements planning, resource – The function of computing long-term requirements on resources such as production facilities, raw materials, or money. A relatively long-range plan is required, as some of the resources (special machines, buildings) must be planned several years ahead.

requirements regeneration – Regenerating requirements and taking into account all changes to the master production schedule since the last plan was generated. Planned orders are recomputed. However, existing released and firm orders are retained by the system. When requirements are regenerated, the old requirements plan is discarded. See "requirements planning, net change".

requisition – A printed authorization to purchase materials or release them from stores. It is created at the time of order release. Requisitions are set up by Order Release as entries in the Stores Control and Purchasing Action Files.

reserving material – Reservation of components and raw materials for use in specific orders. In an integrated computer system, physical allocation is not necessary; reserving components is performed in the computer by the procedure of allocation. See "allocation, firm" and "allocation, preliminary".

resource, associated – A resource whose requirements are not related to specific items but are derived from the requirements for another resource. For example, requirements for setup manpower may be given as a value for the number of shop orders loaded on a work center.

resource, critical – A resource considered in Resource Requirements Planning that has a lead time longer than the normal planning horizon, or whose scarcity may impose a limit on production schedules.

resource requirements planning – See "requirements planning, resource".

rework routing – See "routing, rework".

routing – Sequence of operations to be performed in order to produce a part or an assembly.

routing, alternate – An alternate method or sequence of performing an operation, a series of operations, or a complete routing. The alternate is generally used because of a machine breakdown or an excessive overload on the machines or work centers specified in the "primary" routing. An operation may be replaced by either a single alternate operation or a sequence of operations.

routing, blanket – A routing that lists a group of operations needed to produce a family of items. The items may have small differences in size, but they use the same sequence of operations. Specific times or tools for each individual item can be included.

routing, composite – A routing that lists a group of operations which are needed to produce a family of items, but which are not all used for all items. The operations used depend on the characteristics of each particular item.

routing, raw materials and purchased parts – A routing for raw materials and purchased parts that usually contains special instructions for receiving, inspection, or storage. This type of routing does not carry information describing manufacture of the item.

routing, rework – A routing that shows additional work that must be done in order to rework items that failed to meet their quality specifications. Such routings are often developed only when the problem occurs. In some cases, however, because of a high reject rate during a particular process, the rework routing is held permanently in the routing data.

routing, specific – A version of a standard routing, held at a specific engineering level for an individual customer or product.

routing, temporary – A routing used in making a pre-production item, or used for production planning purposes while the permanent routing is being prepared.

safety lead time – See "lead time, safety".

scrap allowance – A factor that expresses the quantity of a particular component that is expected to be scrapped while that component is being built into a given assembly. Also, a factor that expresses the amount of raw material needed in excess of the exact calculated requirement to produce a given quantity of a part. The factor, dependent upon the type of assembly or part, is carried in the product structure segment and is used to increase the requirements as the component requirements are exploded. Compare "yield factor".

semifinished component inventory – See "inventory, semifinished component".

send-ahead – See "overlapping".

service parts inventory – See "inventory, service parts".

setup time – See "standard setup time".

shipping instructions – See "customer delivery instructions".

shop order identification card – A document, often a punched card, which accompanies a shop order. It is used for order identification, particularly when reporting work via a terminal. It includes shop order number, item number, and order quantity. Other data, such as a brief description, may also be included.

single-level pegging – See "pegging requirements".

specific routing – See "routing, specific".

stabilization stock – Inventory built up to allow for a regular production rate of an item with a seasonal or irregular demand.

staging, material – A procedure used to reserve components for shop orders. Some time before order release, components are taken out of inventory and grouped in a "staging" area. This is not necessary in an integrated computer system.

standard setup time – Estimated or computed time to perform a machine setup.

standard time – Estimated or computed time necessary to perform a given job. When incentives are used, the actual time required will usually be less than the standard time. Consequently, for planning purposes standard times must be corrected by an efficiency factor.

standards for management control – Computed standards of average value together with a statistical deviation for costs, lead times, buffers, delays, etc., that are compared to actual performance so as to identify and display important out-of-line situations as soon as they are recognized.

statistical inventory control – See "order point technique".

storage bin characteristics – A description of a storage bin's capacity in terms of quantity, weight, maximum dimensions of an item, bin type (shelf, vat, rack, etc.), physical location, ease of access, etc.

stores control – Physical aspect of inventory management. Stores control considers how to enter materials into stores economically, keep control of their location, and pick materials for issue.

subcontracting – Having one or several operations performed, or an item built, by an external company called a subcontractor. The subcontractor follows the specifications and instructions given to him.

substitute time – Value used where no standard or estimated time exists. As an example, if the average run time for jobs on center lathes is two hours, this figure can be used as a substitute.

supplier evaluation – Rating of suppliers on the basis of their past performance. Factors used are quality, on-time delivery, price, etc.

teardown – The opposite of setup, taking place at the end of an operation – for example, dismantling of assembly jigs, cleaning of vats or machines, etc.

temporary routing – See "routing, temporary".

text processing – A method of processing free-format text by storing it in computer storage with the possibility of automatic editing and of cutting the text into lines and pages. Additions, deletions, or changes made to the text are automatically edited and printed as part of the new text. This allows revision and updating of texts with minimum typing effort. Printing can be on remote terminals or high-speed printers. Examples of potential applications are parts catalogs, service manuals, quotations subject to correction or modification, etc.

time estimates – See "estimated time".

tool – Any of a broad range of instruments used to facilitate mechanical operations. An implement. The term includes, for example, jigs, fixtures, hammers, saws, twist drills, grinding wheels, milling fixtures, levers, and screwdrivers, as well as machine tools such as grinders, lathes, automatic screw machines, drill presses, etc. For planning purposes, tools that can cause bottlenecks in production (because only one or two units are available) can be considered machines.

tool, consumable – A tool that has significant consumption and is inventoried as a material or supply item. For example, a twist drill or a grinding wheel. If the tool is usually disposed of after a single job, its requirements can be planned as dependent demand. If the tool can usually be reused, its requirements can be planned as independent demand. Also see "demand, dependent; demand, independent".

tool life – The anticipated life of a tool. It is usually expressed as either the number of pieces the tool is expected to make before it wears out or as the number of hours of use anticipated.

tool, permanent – A tool with a relatively long life, such as a jig or fixture. It is usually expensive, is designed to make one specific item or several items of a similar nature, replacement inventories are not usually maintained, and has a long lead time. Requirements for such a tool can be planned by regarding it as a facility during capacity requirements planning. Also see "requirements planning, capacity".

transaction control center – A location responsible for checking the accuracy and validity of transactions.

transaction-driven system – A system that accepts and processes all transactions in a random input stream, and continuously updates and adjusts the plans.

transaction history, inventory – See "audit trail".

transportation time – The average time required to transport parts between two work centers, expressed as a table (matrix). Separate tables can be used for different item classes. Transportation time is an element of move time standards.

Trigger File – A data processing technique used to temporarily store transactions and to automatically initiate processing actions. Within COPICS, the functional areas must be able to accept and collect transactions--resulting either from data collection or as output from another functional area--as they occur. The transactions are temporarily logged in a trigger file until processing is automatically initiated by the functional area. Also see "Action File" for non-automatically initiated actions.

unconfirmed customer order – See "conditional order".

unspecified assemblies – Low-level components that are ordered or produced before their parent assemblies can be identified and specified. They are generally used in the production of large products on special order or for prototypes before the overall design is completed. Because of the lack of data concerning parent assemblies, where-used information is not available. If this data is not provided within a specified period, the system highlights this situation via an Action File.

utilization of machines – Percentage of time a machine is actually being productive (for example, cutting metal), as opposed to being set up, waiting for tools, being idle, etc.

variation (variant) – One of two or more possibilities (for example, manual or automatic gear box) open to a customer when ordering an item. He must specify his choice because the product will not function without it, whereas the product *will* function with or without an "option" (such as a radio). The forecast for a variation is often expressed as a percentage of the product forcast.

wait time – Average time during which completed parts await transportation. It can be a standard for all work centers. Wait time is an element of move time standards.

warehousing – Another term for stores control.

work area terminal – A terminal used to dispatch job assignments as well as to report completion of work. Dispatching instructions are given either on printed copy or on a display screen.

work center – A specific production facility. It may consist of one or several men or machines. It may be organized by type (e.g., a group of milling machines) or it may be a group of dissimilar machines used to produce a part or family of parts.

work center, alternate – A work center that can be used in case of breakdowns or overloads in the "primary" work center.

work center, critical – A work center that is working close to its maximum capacity or where a bottleneck (overload) occurs. Also, a work center that processes the work of an important part of the plant or product line, or one where a breakdown would be critical, or one that consists of a machine with unique characteristics for which an alternate is not available.

work center, gateway – A work center where the first operation of many shop orders is performed.

work center efficiency – Ratio of standard hours to actual hours used. It reflects historic data and is used to adjust the capacity of the work center to a more realistic level.

work measurement – An analytical approach to establishing labor time standards, in which the work content or each work element is "measured" by timing and judgment. It is aimed at reducing as much as possible the subjective factors in setting labor standards.

work order – An authorization for maintenance work. (The term is reserved for maintenance work to differentiate it from authorizations for direct production work, which are called "shop orders".)

work queue – A queue of work that accumulates at a work center.

work station terminal – A type of terminal used to feed back data from the operator's work station on the shop floor to a central computer or control center.

yield factor – A factor that tells by what percentage the quantity of an item or product called for by a shop order must be increased to compensate for expected loss or scrap during manufacture. Compare "scrap allowance".

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