New Jersey Institute of Technology
Digital Commons @ NJIT

Theses | Electronic Theses and Dissertations

10-31-1992

Shop floor planning and control in integrated manufacturing systems

Tahir Mahmood
New Jersey Institute of Technology

Follow this and additional works at: https://digitalcommons.njit.edu/theses

Part of the Manufacturing Commons

Recommended Citation

Mahmood, Tahir, "Shop floor planning and control in integrated manufacturing systems" (1992). *Theses*. 2318.
https://digitalcommons.njit.edu/theses/2318

This Thesis is brought to you for free and open access by the Electronic Theses and Dissertations at Digital Commons @ NJIT. It has been accepted for inclusion in Theses by an authorized administrator of Digital Commons @ NJIT. For more information, please contact digitalcommons@njit.edu.

Copyright Warning & Restrictions

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a, user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use" that user may be liable for copyright infringement,

This institution reserves the right to refuse to accept a copying order if, in its judgment, fulfillment of the order would involve violation of copyright law.

Please Note: The author retains the copyright while the New Jersey Institute of Technology reserves the right to distribute this thesis or dissertation

Printing note: If you do not wish to print this page, then select "Pages from: first page # to: last page #" on the print dialog screen

New Jersey's Science & Technology University

The Van Houten library has removed some of the personal information and all signatures from the approval page and biographical sketches of theses and dissertations in order to protect the identity of NJIT graduates and faculty.

ABSTRACT

Shop Floor Planning and Control in Integrated Manufacturing Systems

by Tahir Mahmood

The implementation of a shop floor planning and control system is a prerequisite in establishing an effective computer integrated manufacturing system. A shop floor control system integrates management production goals with the capabilities and limitations of the manufacturing plant. Shop floor planning begins with a long term rough cut capacity plan and evolves into near term, capacity requirements and input/output plans. Shop floor control provides a status of in-process operations and a measure of the plants success in executing the plan. Effective use of technology on shop floor increases the efficiency of the manufacturing plant. Simulation is an important tools in accomplishing this. The use of simulation for planning and control of shop floor activities is a natural out growth of its application for the design of systems. Simulation, when used for production planning and control, is a useful vehicle for providing the discipline necessary for effective shop floor control in integrated manufacturing systems.

SHOP FLOOR PLANNING AND CONTROL IN INTEGRATED MANUFACTURING SYSTEMS

by

TAHIR MAHMOOD

A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Manufacturing Engineering
October, 1992

APPROVAL PAGE

Shop Floor Planning and Control in Integrated Manufacturing Systems

by
Tahir Mahmood

Dr. Steve Kotefski, Thesis Advisor
Assistant Professor
Department of Engineering Technology

Dr. Raj Sodhi, Committee Member
Director Manufacturing Engineering Program
Associate Professor
Department of Mechanical Engineering

Dr. Nouri Levy, Committee Member
Associate Professor
Department of Mechanical Engineering

BIOGRAPHICAL SKETCH

Author: Tahir Mahmood

Degree: Master of Science in Manufacturing Engineering

Date: October, 1992

Undergraduate and Graduate Education:

- Master of Science in Manufacturing Engineering, New Jersey Institute of Technology, Newark NJ, 1992.
- Bachelor of Engineering in Mechanical Engineering , N.E.D University of Engineering and Technology, Karachi, Pakistan, 1984.

Major: Manufacturing Engineering

Professional Positions:

- Teaching Assistant, January,1992-May,1992 Department of Manufacturing Engineering.
- Teaching Assistant, August,1991-December,1992 Department of Mechanical Engineering.
  New Jersey Institute of Technology, Newark, NJ.
- Deputy Manager, August,1987-August,1990, Corning Glass Ltd., (A subsidiary of Corning Inc.) Karachi, Pakistan.
- Assistant Works Manager, October,1984-August,1987 Heavy Rebuild Factory, Taxila, Pakistan.

This thesis is dedicated to
my parents

ACKNOWLEDGEMENT

The author wishes to express his sincere gratitude to Dr. Steve Kotefski, whose valuable guidance, constant inspiration, and encouragement, made this thesis possible.

Special thanks to all the faculty members of the Manufacturing Engineering Department who shared their knowledge of this thesis topic.

A special appreciation is due to Dr. N. Levy whose teaching helped the author a great deal, and opened a door for his experience as a teacher assistant of the same course.

The author is also grateful to Dr. R. Sodhi who most generously made all the required facilities available during the period of studies.

Finally a thank you to friends Anwar, Azam, Hari, Sylvia, Odell, Tanweer and Ramesh for their unique cooperation.

TABLE OF CONTENTS

List of Figures

CHAPTER 1
INTRODUCTION

We live in a complex environment where rate of change is accelerating. The impact on manufacturing is particularly acute. Modern manufacturing management can no longer meet the challenge of doing business today without reacting more rapidly to the environment. The fragmentation so prevalent in manufacturing management must be replaced with an integrated system regulating the production flow to meet the varying demands at least cost.

The manufacturing strategy may take many forms to reflect different planning and control needs, but its purpose is always to highlight the utilization of the resources. In some cases, it may be thought of as an in-depth model of a factory segment, while in others it appears as a bill of material or as a report of completed activities. In any case, its role is closely linked with the techniques of shop floor control to which it lends a reference frame work and operational tools.

As manufacturing companies strive to achieve increased efficiencies, they must make a effective use of technology. The subject of Computer Integrated Manufacturing (CIM) has received much attention during the last five years. The implementation of a shop floor planning and control system is a pre-requisite to establish an effective CIM system. A shop floor control system integrates organization's goals with the capabilities and limitations of the manufacturing plant. Shop floor control provides a status of in-process operations and a measure of the plant's success in executing the plan.

Simulation is an another form of technology, when used, provides the discipline necessary for effective shop floor control. Simulation is an analysis tool that is essential to successful implementation of Computer Integrated Manufacturing, which allows manufacturing engineers to better control the interaction between shop floor components.

The study of a real time shop floor under complex and dynamic conditions, becomes not only tedious but rather impossible. The models can be simulated with a very close resemblance to the real time systems.

The objective of this thesis is to study that how modern technology can be used to control shop floor activities in an integrated manufacturing environment, and to analyze the shop floor system's performance measures. Machine Utilization, Queue Length and Job Flow Time has been considered as performance measures. Effects on performance measures has been analyzed at different job arrival rates having Normal, Exponential and Uniform distributions. SIMAN language is used to develop simulation models. Three different models were developed of a shop floor having fifteen machines which can perform eight different operations. The job mix consists of six job types, each type having a machine visitation sequence with known precedence order. Each product requires different operation time on each machine.

Models simulated using related methodology, statistics collected , results analyzed and finally the conclusion has been made.

CHAPTER 2
SYSTEMS INTEGRATION

2.1 Introduction

Today cost, quality, productivity and time to market, issues resulting from global competition and shorter product life cycles have made systems integration critical to the success and survival of manufacturers. For those both in discrete and process industries, integrated communications and controls are viewed as a strategic tool for staying competition. The benefits associated with increased automation are substantial, but full potential is not realized until the automated processes are integrated to share all manufacturing information. Currently, only a limited number of these processes communicate outside their own boundaries, creating thousands of 'automation islands'. integrating these islands of automation will be essential to creating factories of the future.

Though there is currently much emphasis on integration in manufacturing, this does not mean that integrated systems did not exist in the past. The 20's and 30's witnessed the creation of complex industrial systems, which were usually the brain child of a single visionary, who was the integrator. Many of these plants were designed to be, and truly were, highly integrated plants. It was in this period that Henry Ford built the River Rouge plant, described by some as the most awesomely integrated plant ever built

(Halberstam, 1986). The production of a complete car, from raw material to finished product, took only four days. Integration was also inherent in the old German art of manufacturing called Technik. Clark and Hayes (1988) describe Technik as the "mastery of the whole complex interplay of processes, product design, and related activities," the basic skills of an integrator. But, whereas in the past Integration was relatively easy to achieve, increasing levels of technological complexity coupled with increasing functional specialization, have made integration increasingly difficulty to attain today.

During the past decade we have witnessed the rapid development of a variety of process related technologies e.g.. robots, NC machines, CAD etc. During the same time the development and practice of integration methods, technologies, and procedures has been relatively slow. The lack of growth is partly responsible for the islands or sub-systems of design, automation information systems that engineers often complaint about. To achieve real integration we need to progress beyond these sub-systems of efficiency.

2.2 Systems Interrelationships

A system may be described as a set of interrelated elements or sub-systems. Based on the nature of these interrelationships, different types of systems can be configured. Two of these interrelationships are interfacing and integration. Mize (1987) defines these two interrelationships as:

Interfacing: To interact or communicate with another element.

Integrating: To organize various traits , relations, attitudes, behaviors, etc harmonious personality.

Many of today's system designers stopped at interfacing and anticipate the benefits of integration or trying to behave in an integrated fashion, but do so at a high cost because duplicate information and decisions, are constantly being recreated, reproduced, transmitted, and stored in information systems.

Mize definition of the above two relationships can be extended to define four types of systems in general. These are, shown in figure 2.1.

1- Stand alone

2- Interfaced

3- Integrated

4- Universal

A stand alone system is one whose elements make their own decisions and do not communicate with any other element. An interfaced system is one whose elements have one or two way communication with other element, but make decisions for their own benefit. An integrated system is one whose elements have two way communication with other elements, and make decisions for the collective benefit of the system. Thus, interfaced system have parasitic relationship, while

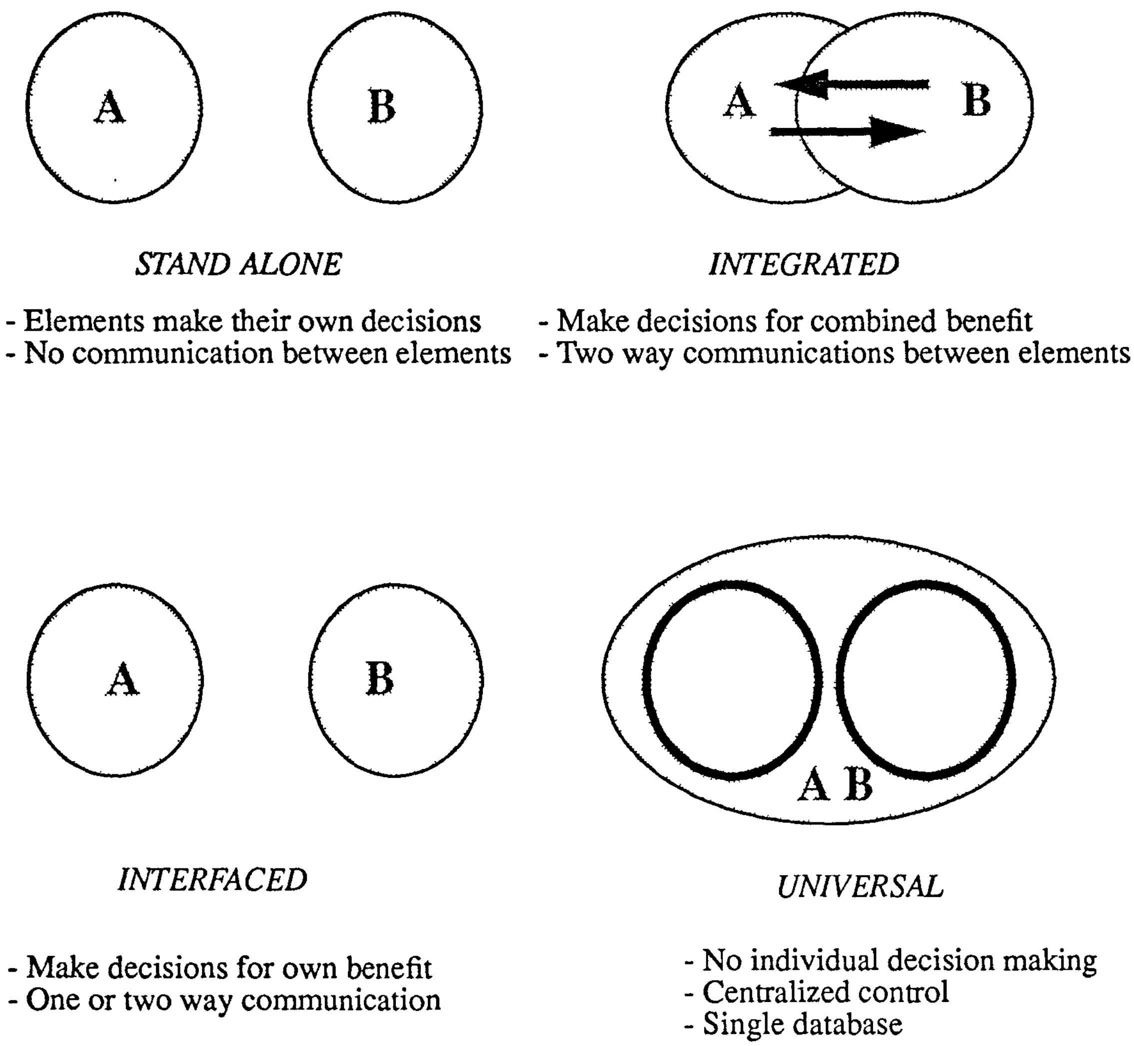


Fig 2.1 Different Types of System Interrelationships

integrated systems have a symbiotic relationship. A universal system is a group of elements with no individual decision making capability, and a central controller. In searching for integration some system designers have fallen into the 'universal' trap and built systems with a single database and no distributed decision making. While theoretically this appears to be an ideal situation, it has several practical drawbacks. These definitions indicate integration is not just a network, nor is it simply a unit system. Further, there is no good/bad description of any type of system. A manager must decide which type is best suited to a particular application. For instance, it is desirable a nuclear power plant be a universal system. While, a team of racing cars should be interfaced, since an integrated approach may provide a higher average ranking but not a winner.

2.3 A Definition

Systems integration is a very straight forward concept. We will define it simply as follows: "The optimization, over time, of all the elements comprising an organizational system that generates a measurable output. These elements include all the organization's fixed, potential, tangible and intangible assets, including people, money, information, capital investments, energy and technology".

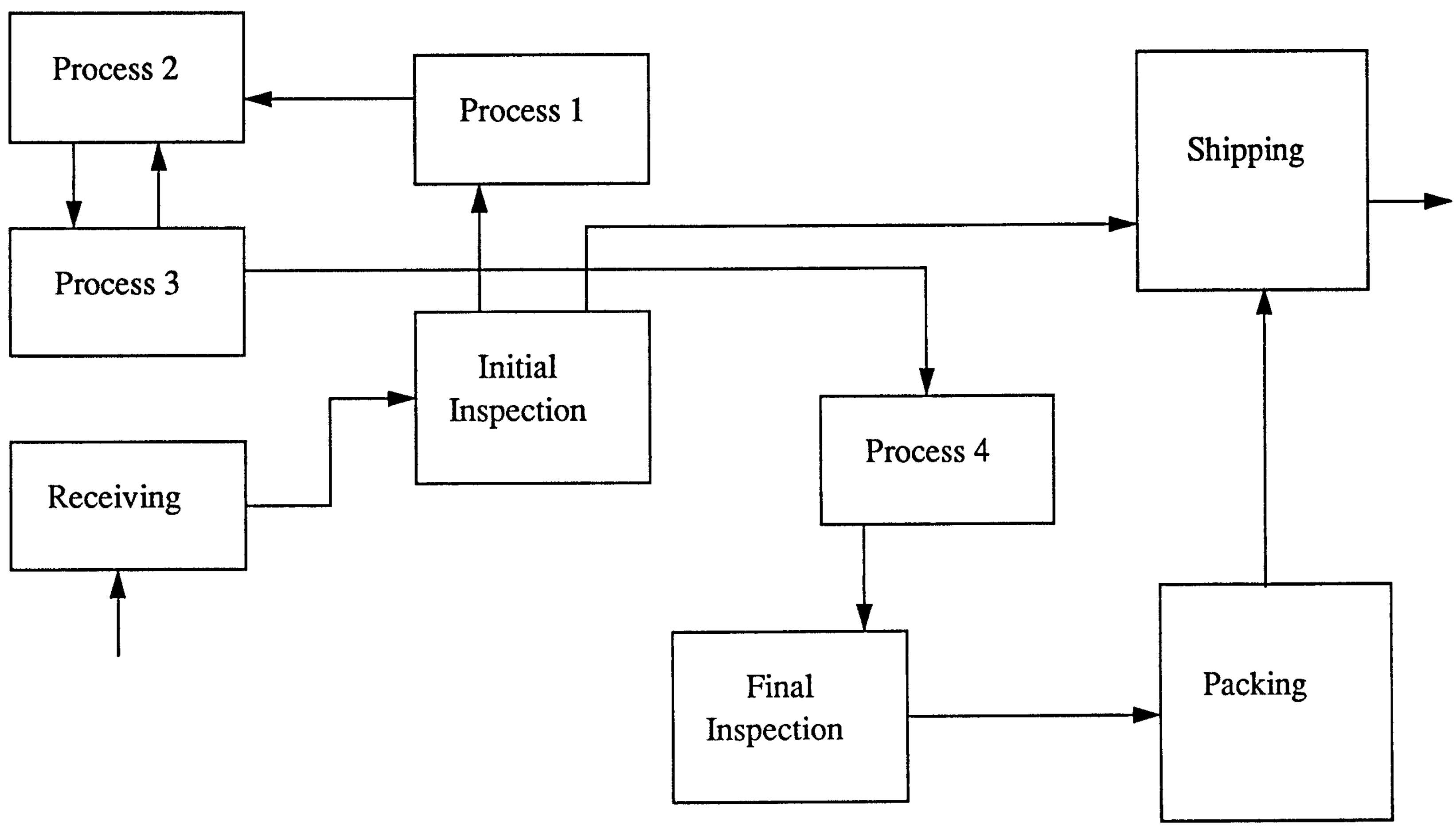


Fig 2.2 System Functions Before Integration

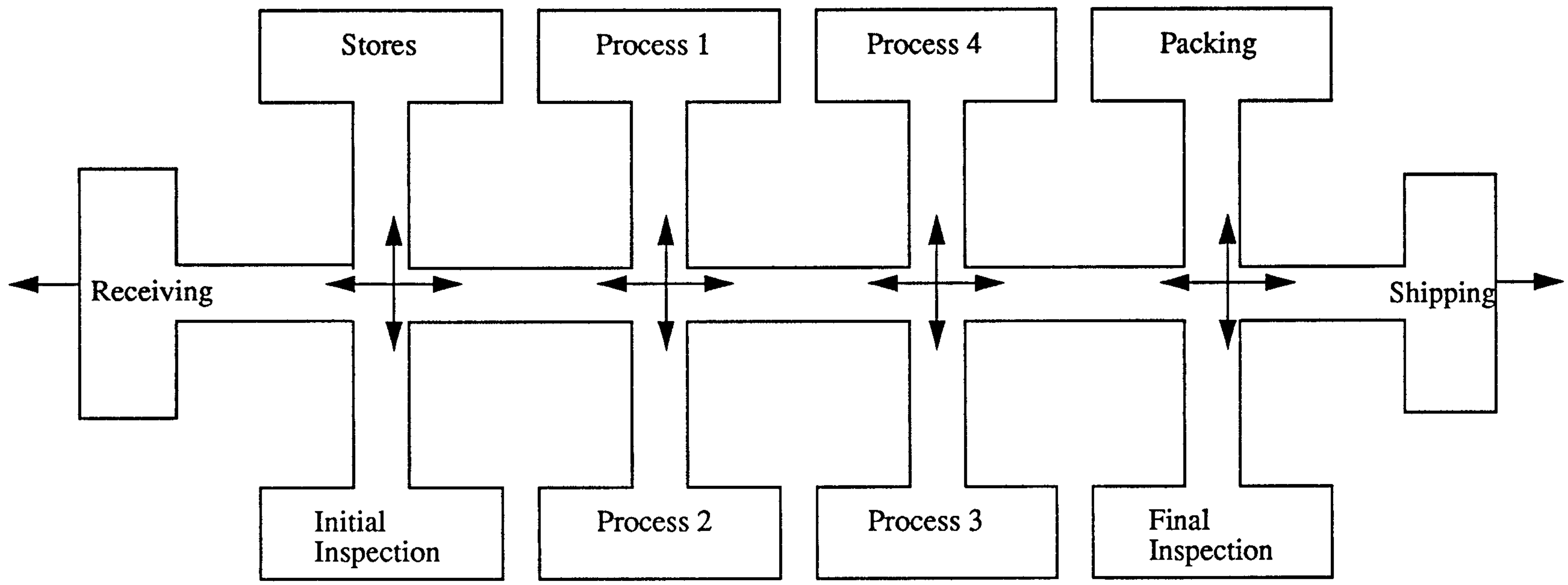


Fig 2.3 System Functions After Integration

2.4 Types of Integration

The variety of integration practiced in industry often differ in either the medium of integration, or the entities being integrated. Most commonly though, the medium will be some data transfer mechanism. In fact efficient data handling capability is considered as a prerequisite for integrated system.

Integration can be categorized into two types:

Resource Oriented Type : Integration which concerns a physical resource, where the resource is used either directly, or indirectly in the manufacturing operations.

Activity Oriented Type: Integration which refers to facets of the different manufacturing activities. The two divisions are analogous to the user and technology views, since most of the physical elements are technology based while the activity elements are user based.

Further these two types can be divided into nine categories of system integration as:

2.4.1 Resource Oriented Integration

Resource oriented integration may be viewed as the hardware portion of the integration problem. The objective of these types is first to ensure that the functions of each resource are supportive of the entire manufacturing process, and then second to ensure the compatibility of these functions with other related functions. The four integration types in this division are:

2.4.1.1 Computer and Network Integration

Concerns the design of computer and network systems so as to permit portability of programs between all organizations computers, and to permit data transmission and receipts from all desired nodes. We define a computer and network system as consisting of executable computers, communication networks, and data storage and retrieval devices. Database management systems(DBMS), distributed database architectures, local area networks (LANS), open systems interfaces (OSI), and sub-system gateways are just some examples of solution technologies available for this integration type. Specific research and development projects in the area include, IEEE Project 802, Manufacturing Automation Protocol (MAP), and the Office Protocol System (TOPS). The primary obstacle to computer and network integration is the diversity in computer platforms and equipment located at each node.

2.4.1.2 Equipment Integration

In any manufacturing setup there are a variety of different equipment. These equipment include production machine, material handling equipment, storage and retrieval devices, and support equipment. Equipment integration is concerned with the design and selection of equipment so that each equipment interfaces well with the relevant people, materials, handling devices, tooling, controllers and other equipment in the plant. With the increasing use of automated and semi-automated equipment, this type of integration is becoming increasingly critical.

2.4.1.3 Facilities Integration

Facilities planning is traditional subject of industrial engineering, and most facilities planning techniques are based on an integrated approach. The common methods focus primarily on optimizing material flow. But the design of facilities considering information flow, inventory reduction, group technology requirements, quality control, and cellular and automated manufacturing is needed for achieving facilities integration. In the coming years manufacturers will have to build a significant number of new facilities and modernize existing ones, in order to remain competitive. These developments must emphasize facilities integration.

2.4.1.4 Material Integration

The selection of materials for production is usually based on functionality and cost. Material integration is concerned with certain specifications associated with a selected material. For instance raw material dimensions, or acceptable quality levels. These specifications are designed to minimize material related interferences on product manufacture. Factors such as, vendor reliability and behavior, quality maintainability, handling ease, etc., are considered in this type of integration.

2.4.2 Activity Oriented Integration

The objective of the activity oriented integration types is to ensure that minimal effort is expended, and maximum benefit is derived, in the execution of manufacturing activities. The five integration types in this division are:

2.4.2.1 Process Integration

The manufacture of a product may be broken down into a sequence of processes, each of which contributes to the value of the product. Process integration concerns the selection and design of processes, such that a minimum effort is expended in transferring the semi-finished product from process to process. For instance, let a product be manufactured by two processes A and B, with effort C expended in transfer. This effort could include material handling, reorientation, refixturing, etc. Then process integration is concerned with the selection and design of A and B such that C is minimized. A lack of process integration could greatly increase production costs and degrade performance. Computer aided process planning methods, and setup reduction methods are examples of process integration solution technologies.

2.4.2.2 Information Integration

Manufacturing may be viewed as a series of data processing operations. This data could be in the form of a bill of materials, production schedule, process plan, product drawing, CNC machine program, robot control program, quality control chart, etc.. Information integration is concerned with generating and utilizing this data in an effective and efficient manner. Thus information integration differs from computer and network integration which is concerned only with making the data available at user nodes on request. Information integration attempts to ensure first that the accessed data can be transformed into appropriate activity decisions, and second the data can be deciphered or comprehended by the user. This leads to the following two sub-categories of information integration.

2.4.2.3 Transformation Integration

Concerns the ability of users to utilize the accessed data in their sub-system activities. This implies the user must know what data is needed, what is available, and where it is located. The primary purpose of a MIS is to provide users with information that will enable them to make better decisions. In the absence of transformation integration, decisions made in the presence of the data and its absence will be no different.

2.4.2.4 Transactional Integration

Since data can be portrayed in many different formats, transactional integration is concerned with having a common data format which is readable and comprehendible by all users. This common format may not necessarily be used within the subsystem, but will permit translation into it. For instance, the Initial Graphic Exchange System (IGES) provides such a format for CAD files. Also implied in this integration is restricted data input and change. Other example technologies in this area are bill material (BOM) generators which are able to create a BOM from CAD file, and the Product Data Exchange Standard (PDES). Alternatively, transactional integration requires a well designed data input, storage and presentation procedure.

2.4.2.5 Decision Tool Integration

A variety of decision methods or tools are used in manufacturing. This integration ensures that the objectives of each of these tools is complementary to the overall objectives of the facility. For instance, a robot controller attempts to complete the job in the shortest time, but this objective could imbalance the line and lead to other problems. The robot should therefore try to minimize imbalance, and could use the extra time to improve job quality. Decision tool integration is being increasingly practiced in integration efforts today, and it holds the key to evolving from an interfaced system to an integrated one. Another example of this integration is Total Quality Management (TQM). Independent methods of quality assurance, quality control, and customer service have been successfully integrated under the TQM umbrella by many companies.

2.4.2.6 Control Integration

While decision tool integration concerns the process by which decisions are made, control integration concerns the identification of the decisions themselves. This integration ensures that the decisions and controllable variables of the sub-systems are supportive of each other and complementary to the overall objective of another. This integration also requires achieving an appropriate breakdown of the manufacturing strategy from the senior management level down to the machine level. Hayes and Wheelwright (1984) identify consistency and contribution to competitiveness, as criteria for evaluating a strategy. Both of these are closely linked to integration and are Critical to the success of a integrated system. Control, decision tool, and information integrations together form a closed loop, which may be described by the following: the right information ensures best use of the tools, the right tools ensures best decisions, and the right decisions ensures the best system. Identifying the right decisions can be harder than it seems, since it requires insights into the subsystem and its related subsystems. The U.S. Air Force has developed the IDEF methodology as a tool to support the design of integrated manufacturing systems (IDEF

Manual, 1981). This methodology specifically focuses on information, decision, and control integration.

2.4.2.7 Product Integration

This integration attempts to optimize the manufacturability of the design. Manufacturability is a function of the ease of production, ease of scheduling, level of output quality, and inventory implications. Most products can be designed in several ways, each of which could be equivalent in terms use of customer satisfaction, but have different degrees of difficulty to produce. Product integration ensures that the most convenient design is chosen. Methods such as design for assembly by Boothroyd and Dewhurst (1983), or three dimensional design animation are examples of applicable technologies.

2.5 The Need For Integration

The need for integration has evolved in response to a set of specific problems which arise as a result of the traditional process of industrial automation. These problems were articulated in a special study done for the United States Air Force Integrated Computer-Aided Manufacturing (ICAM) program. This study of the state of industrial automation found five crucial problems:

1. Users cannot control information.
2. Change is too costly.
3. Systems are not integrated.

4. Data quality is poor.

5. Systems take too long to change.

These problems arise from a job shop approach to automation. This approach takes specific sets of user requirements and discovers special technical solutions for each of them, creating what have come to be called "islands of automation" and "islands of data". These islands can sometimes be interfaced (cross referenced) after the fact, but they can never be fully integrated. Interfacing is accomplished by wiring independent islands of automation together. Integration is accomplished by creating individual solutions which share common parts, such as data. The job shop methodology which created islands of automation looks for specific vendor technical solutions to specific user requirements. Each solution has its own unique input, output, storage, and processing structure. Each may also have its own hardware, data management, programming, and communications structure. The problem is that while user requirements tend to change rapidly in response to market, political, social, and managerial forces, technical solutions do not. Technical solutions respond to whatever forces are driving individual vendors. The islands of automation approach not only places individual user requirements at the mercy of specific vendor solutions (often holding them hostage); it allows for individual vendor solutions to be inconsistent, incompatible, and generally not shareable.

2.6 Benefits of Systems Integration

The following are some of the general benefits that flow from integration:

1. Improved product quality through error reduction
2. Prototype simulations and evaluations prior to manufacturing and support.
3. Shorter design time to meet customary request.
4. Ability to evaluate more alternatives.
5. Better control of materials and other resources.
6. Improved tracking of manpower and project activity.
7. Better comprehension of the nature of design in the context of product options and their impact on downstream functions.

CHAPTER 3
INTEGRATION IN MANUFACTURING SYSTEMS

3.1 Introduction

Manufacturing stands on the threshold of a new era in which all manufacturing enterprises must compete in a global economy. A gloomy view of this new economic environment can project dismal consequences for the quality of life in America. A more optimistic view recognizes that despite challenges to the nation's economic and technological strength, this fundamental change in the competitive environment presents opportunities as well as challenges. Indeed, it is possible to imagine a future of economic growth and prosperity on a global scale.

One thing that can be said with certainty is that all sectors of society will undergo profound changes. Consequently, many manufacturing practices that were effective in the past will no longer be so in the future. Those companies that prosper and those that fail may well be distinguished principally by their ability to plan for change. Moreover, we can expect the economic environment to remain highly dynamic, so changes must be confronted with the expectation that they will be continual.

Fortunately, there are many options open to companies that understand the dynamics of this situation. The problem that they face is to identify, from among the rich universe of possibilities, those opportunities that represent the best investment of limited resources.

There are many conflicting voices speaking to manufacturers. Some emphasize automation equipment; other say that the data network is key. Noting delays in process flows, some suggest that attention to material handling is essential; others argue that it is only the processing steps that add value. Some put the primary burden for reform on management, some on the workers, some on suppliers, and so forth. .CAD, CAM, CAE, JIT, SQC, MAP ,MRP - the list of abbreviations for promised solution - goes on and on. How we can make sene out of all of this? All these work as "islands" of automation. However we all realize that the real world does not allow isolation of subsets of problems that are solved independently of the others. In reality, each problem subset imposes certain constraints on the solution of the others and the whole.

3.2 Complexity in Manufacturing

Manufacturing is no longer just a case of making a simple product in a single plant; quite frequently today it is a complex interwoven system of making a number of products in a number of plants with the raw materials and subassemblies for a day's production often not even in the plant. In the case of one bottler, the empty bottles are delivered at one end of the plant and the filled bottles shipped from the other, almost in a continuous pipeline. In the case of a nationwide frozen-food bakery, there is never more than one day's consumption stored in the plant at any one time. In the case of a production-level problem of output below expectation may required another workstation for its solution, but this may be economically unfeasible because the funds had to be used to solve a materials problem. The materials problem may be caused by a design that is not workable, requiring more exotic and hence more expensive material. Thus the new facility cannot be purchases because funds are needed to buy material at a greater cost since a perdurability engineering problem went unsolved.

3.3 The Need for an Integrated Solution

By integrated we mean that all the resources the company has will be brought to bear on the problem at hand. We are looking for a solution that transcends manufacturing engineering, and even the manufacturing function in total, requiring the resources of most if not all function of the company. We wish to discover how to make quantum jumps in improving productivity and thus profitability. Manufacturing engineering skill will be important because they are involved in all technical aspects of the factory operations. But other will also be involved because productivity is a measure of total output divided by total costs to obtain a cost per product value. The productivity improvement problem is to reduce the cost per product value; the lower this becomes, the more profitable the company becomes. It is easy to see that much more than manufacturing costs are involved. Beyond the labor and materials costs we must consider the entire overhead cost structure of all segments of the company. Therefore, the impacts of design engineering, marketing, finance, and employee relations on cost must also be analyzed and reduced to solve the productivity problem.

This over all approach to improving productivity is the only rational one. It makes no sense to have manufacturing drive down factory floor operation expenses if design engineering is adding cost to the product. If we are fortunate, the net effect is close to zero. If both functions are working to reduce costs - manufacturing is operating cost, design engineering in costs of tolerances required and materials selected - then the reductions are additive and the results are significantly greater than zero and beneficial.

Traditionally, each function has looked after its realm of responsibility in relative isolation from the other functions. This method is never optimal, because we are not sure we are spending company resources where we obtain the best results. Each function is competing against the other functions for limited resources and the resources can unknowingly be misapplied.

All too often, each function is left to establish a cost reduction plan relatively independently. The result is that the overall picture of opportunity is never seen and we have tactical rather than strategic plans for improvement. For example, within manufacturing a great deal of effort may be expended to reduce direct labor costs by achieving greater workstation effectiveness rather than to reduce the cost of materials, because direct labor productivity is under the control of the manufacturing function. Manufacturing has shop operations to monitor and control work attention time and adherence to methods, manufacturing engineering to design efficient workstation and methods to reduce the time to do the required work, quality assurance to monitor manufacturing losses and feed back corrective action request, and even materials to batch stock to make effective production runs. Therefore, manufacturing can make and all-out assault on direct labor costs, that is productivity.

Let us look at the materials situation. Here manufacturing can only affect the purchase price negotiations and perhaps argue successfully for reduced tolerance rigidity so that less scrap is created. But the real savings is in substitutions for materials - using cheaper grades of steel, for example. These substitutions are the domain of design engineering, not manufacturing. Hence the big reduction is not sought as it should be because it lies in the sphere of responsibility of design engineering and not manufacturing. Why does design engineering not respond to this challenge? There are a few good reasons. First if left in isolation, design engineering would consider productivity improvement to be the ability to produce design faster and with fewer people. This affects the deign engineering budget in a positive way. Second, design engineers tend to design Cadillacs when stripped-down Cerecloths would be adequate. This is referred to as protecting the design margins,. Third, perdurability engineering is a manufacturing activity; therefore, there is little reason to expect design engineering to search effectively for the cheapest material if using it requires a design compromise. The result of these productivity improvements in isolation is an extreme under establishment of the materials cost improvement goal. The solution is to have an integrated attack on the most lucrative area of the cost reduction potential. In a integrated program the perdurability and advanced manufacturing engineers would look for ways to make the products with cheaper materials, while the design engineers would evaluate the changes in design needed to allow such materials to be used. In addition, manufacturing engineering would work on methods with the primary objective of saving material and the secondary objective of saving worker time. Purchasing would focus its negotiated price activities on the lower-cost materials that design engineering is striving to use. In this integrated approach the different functions are working toward the same goal. When the functions worked independently and only looked at their portion of the business, this goal was secondary in importance. Thus when the functions are taken out of isolation and given the opportunity to see the area where the greatest overall gain can be made, we can have a quantum jump improvement in productivity.

3.4 The Role of Computer in Integrated Systems

The challenges of today - the need to improve productivity, product quality and reliability and reduce costs - cannot be met by just better machines and skilled operators. There must be better managerial tools and integration of the various disciplines to define and produce the products that will allow you to take advantage of existing resources ; both machines and operators. The one single tool that can meet those challenges in a cost-effective manner is computer technology.

With the invention of the electronic computer it was quickly realized that this tool had an enormous potential for becoming the focal point in future automation endeavors. Conventional automation was based primarily on sophisticated mechanical machinery controlled by cams and lever or electrical switching gear. The equipment in general was conceived to perform fixed manufacturing assignment . The degree of automation that can be achieved with these tools is limited since for more demanding tasks the controls become so complex that they cannot be justified economically. The original automation endeavors were directed primarily toward the improvement of the machining c

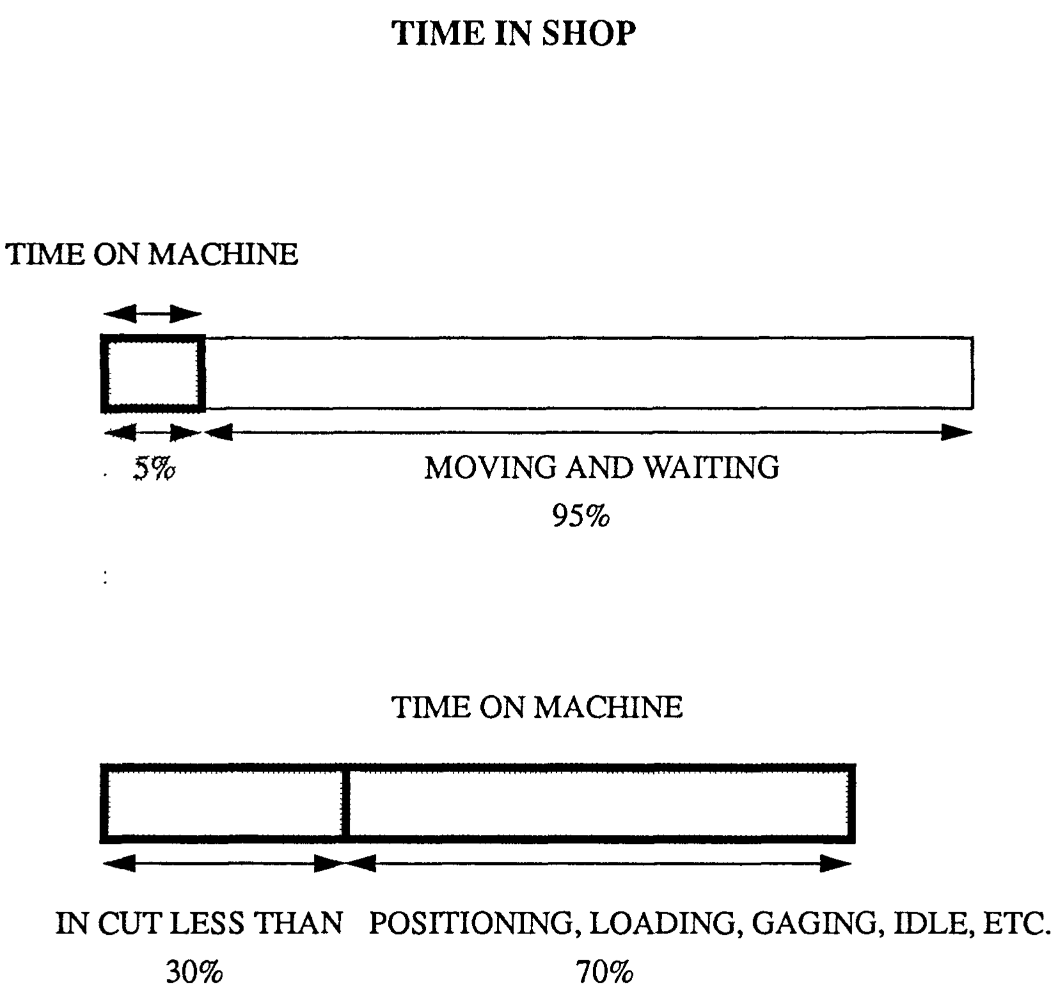


Fig 3.1 Life of the Average Workpiece in the Average Shop

capabilities of the manufacturing equipment. However, the average time a work piece spends in a machine tool is only about 5% of the total time it spend in a factory as shown in figure 3.1. It is apparent that the long in-shop time results in a high inventory of unfinished and finished parts. If this idle time could be reduced, large amounts of capital would be available for more productive tasks. It is also well known that the average machine tool is used on 6% of the time available. The productive time could be improved by automatic loading and fixturing of parts, the use of group technology, and the employment of second and third shifts.

Whereas early automation endeavors were concentrated on the improvement of machining operation, at present attention is focused on the 95% nonproductive moving and waiting time. As a matter of fact, most present research effort in manufacturing is concerned with the possibility of reducing this idle time, thereby increasing machine utilization and productivity. Since the task is very difficult to perform with conventional automation tools, the computer plays an ever-increasing role.

3.4.1 Computers - Today in Manufacturing

Computerized systems are not being designed to replace the rigid boundaries of discrete functional departments with an integrated flow based on a logical sequence of events. This series of steps flows from product design to robotic

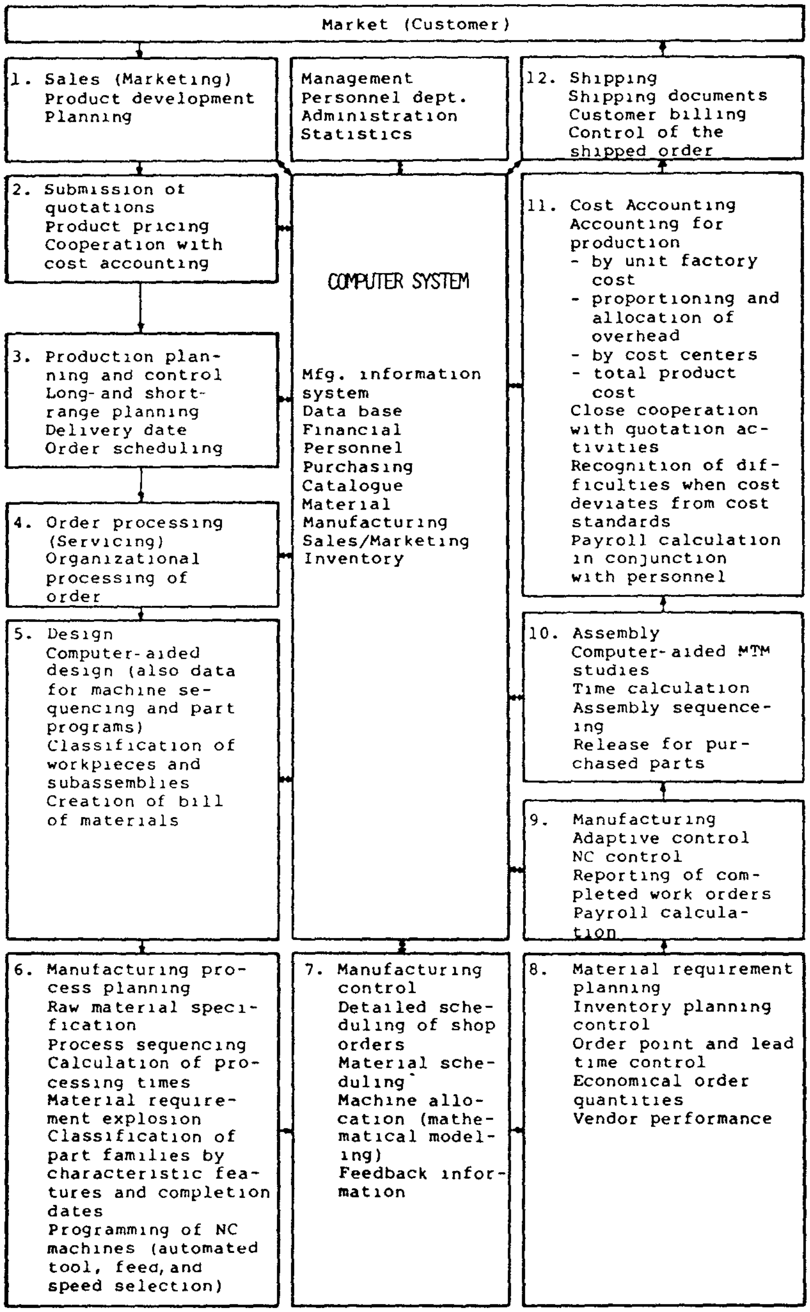


Fig 3.2 Computer Functions in Manufacturing

instruction, selection of optimum production processes, automatic creation of computer numerical control (CNC) tapes, modeling simulation of the complete process, flexible manufacturing and assembly, computer-based planning, scheduling and shop floor control, automated materials handling, warehousing and distribution, cost control, and worker-productivity measurement techniques.

In this environment, corporate strategies have to be developed based on long-term commitment to change in the context of the whole enterprise rather than as a conglomerate of individual organizational components.

Today, computers are much more powerful and much less costly than their predecessors. Inputs devices have achieved faster response time, and with the advent of voice recognition, radio frequency systems, laser technology and optical scanning devices, they are more attuned to the needs of plant operations. Conventional keyboards, which are cumbersome as a worker input station, are being replace by audio command (particularly in process inspection), and touch-sensitive screens.

Common data bases are being developed to enable storage and retrieval of pertinent data by design and manufacturing engineers, production planners, manufacturing, purchasing, and MRP personnel, inspectors, cost accountants, and others. These data bases are being design as both distributed and integrated networks. The user may have either selective or complete access to these common data bases, often without

	Indirect application	Direct application
Plant level	Direct planning models Accounting systems Production management systems Computer aided design	Computer aided warehousing Direct number control Flexible manufacturing systems Automatic storage and retrieval system
Operation level	Computer aided process planning Computer aided work measurement Computer aided NC programming	Computer aided testing Computer numerical control Computer based automatic assembly machines Robots

Fig 3.3 Computer Applications in Manufacturing

knowing where the data physically resides. The information comes from many sources and can be available in virtually any format desired.

3.5 Future Trends in Manufacturing

Industrial technologists of the world have forecast that the over all future trend in engineering and manufacturing between now and the year 2000 is toward the development and implementation of the computer-integrated manufacturing. Very significant economic and social incentives are at work to provide motivation for this to happen. The strategy being followed is to develop and implement a sequence of viable economic steps in a shorter range program to bring about the eventual realization of the overall objectives. These objectives include development and implementation of new optimization technology, including integrated engineering manufacturing databases, group technology, cellular systems, and full manufacturing management systems and their applicable, complex software systems, including the latest development in interactive graphics, computer-aided engineering, computer-based business systems, and office automation - including word processing, electronic mail, teleconferencing, etc.

CHAPTER 4
COMPUTER INTEGRATED MANUFACTURING (CIM)

4.1 Introduction

The subject of computer-integrated manufacturing (CIM) has received much attention during the last five years. Computer applications in the manufacturing area have experienced a relatively unplanned growth pattern. Computer applications have proceeded on several fronts at the same time, and manufacturing engineers have simply taken advantage of the opportunities. The problem is that now there are so many computer applications that it is difficult to manage them all.

4.1.1 What is CIM

CIM is the philosophy that all production and information technologies must work together. CIM is the way of looking at the firm's production resources as a single system and defining, funding, managing and coordinating all improvement projects in terms of how they effect the entire system. CIM is a system's view of production rather than the past molecular view of only dealing with the parts separately.

A fully integrated CIM system involves the design , development , or application of each of the systems in such a manner that the output of the one system serves as the input to another . For example , at the business planning and support level , a customer order servicing system receives input from the sales force relating to discriptions of products to be purchased by prospective customers . The product description serves as a input to the engineering design function . If the product contains previously designed components , a computer - aided design system would output the engineering drawing information to the bill of materials processor and process planning system . If the product discretion contains new components , the discretion would serve as input to a computer-aided designs system where interactive graphics could be used as a design aid to provide engineering and manufacturing information . Complete implementation of CIM results in the automation of the information flow in a business organization from entry of an order through every step in the process to shipment of the finished product .

Computer-integrated manufacturing systems are expected to dominate the factory automation movement within ten years. Computer-integrated manufacturing will be tied into larger scale manufacturing systems, but it is valuable to consider the computer-integrated manufacturing as a critical unit or building block in total factory integration. A computer-integrated manufacturing may be described as an integrated system of machines, equipment, and work and tool transport apparatus, using adaptive closed-loop control and a common computer architecture to manufacture parts randomly from a select family. The hardware components of a computer-integrated manufacturing may include an NC tool, a

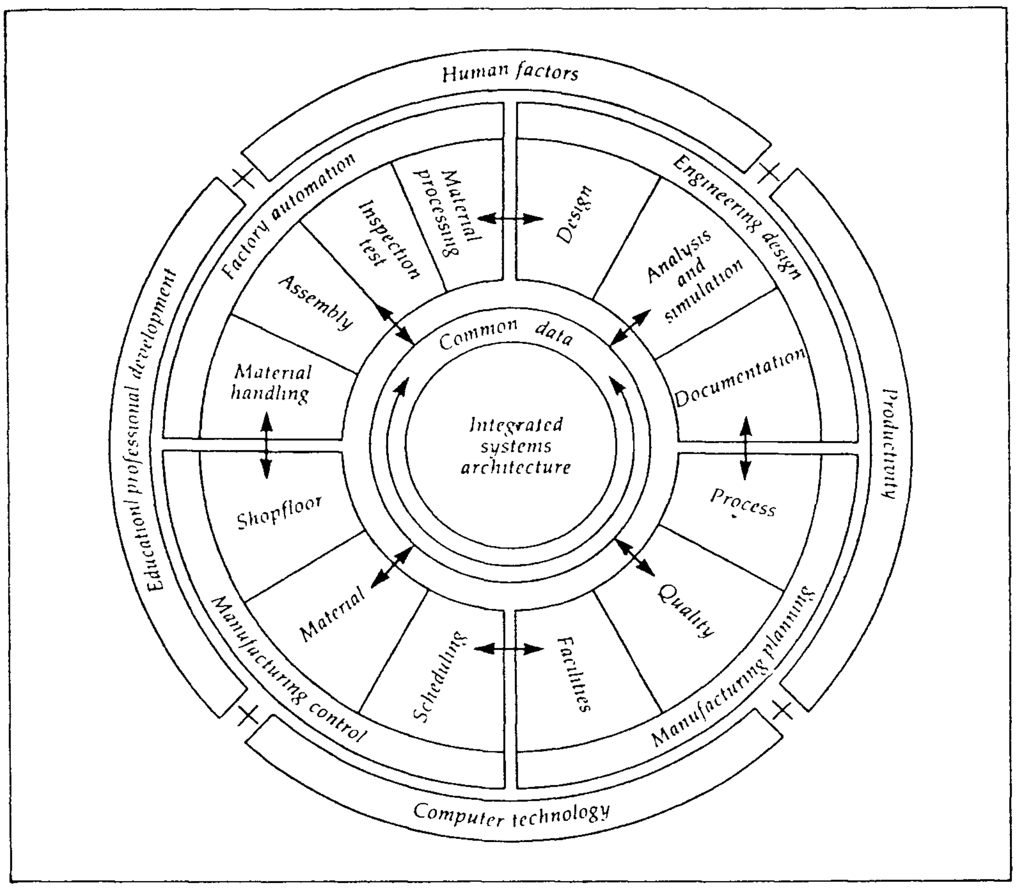


Fig 4.1 Model of a CIM System

robot, or an inspection station. The part family processed by the computer-integrated manufacturing is defined by GT classification. For greatest productivity, the computer integrated-manufacturing is optimized to produce only one family of parts, and conversely, the parts produced by the computer-integrated manufacturing are designed to facilitate processing by the computer-integrated manufacturing.

The concept of flexibility as used in a computer-integrated manufacturing includes:

1. Use of GT to achieve a part mix of related but different parts.
2. Batching, adding, and deleting of parts during operation.
3. Dynamic routing of parts to machines.
4. Rapid response to design changes.
5. Making production volume sensitive to immediate production of parts on demand.
6. Dynamic reallocation of production resources in case of breakdown or bottleneck.

Companies all over the world are focusing their efforts on the development of CIM systems. However, the structure and nature of these efforts vary greatly, primarily due to differences in their interpretations of CIM, the scope of their CIM efforts, and the large number of potential CIM technologies. These differences make it difficult to transfer CIM experience from one company to another, or to create a common knowledge base for CIM technologies.

Further, the extent to which these efforts are successful in achieving CIM is not always easily determined. Allen-Bradely built a new plant in Milwaukee based on the CIM philosophy. The venture has been a success, with raw-materials inventory being completely eliminated and a quality level of only fifteen parts rejected per million produced.

Efforts are underway at many companies to use CIM philosophy to increase their productivity and profits. The hope is that automated, integrated factories will produce parts which are of higher quality, cheaper and on time.

4.1.2 Goals of CIM

The goals of a CIM program are:

1. *Reduce production lead time.*

Install CAD, CAE,and CADD software programs to approach zero time in design, engineering, and drafting.

2. *Create balanced production lines.*

Install balanced production lines to achieve zero work-in-process queues.

3. *Develop capability to produce in a lot size of one.*

Develop the system so that when a customer's order is received for one part, the manufacturing facility is able to procure raw materials and labor or produce one part.

4. *Achieve zero setup time.*

Develop improved methods that will reduce setup time

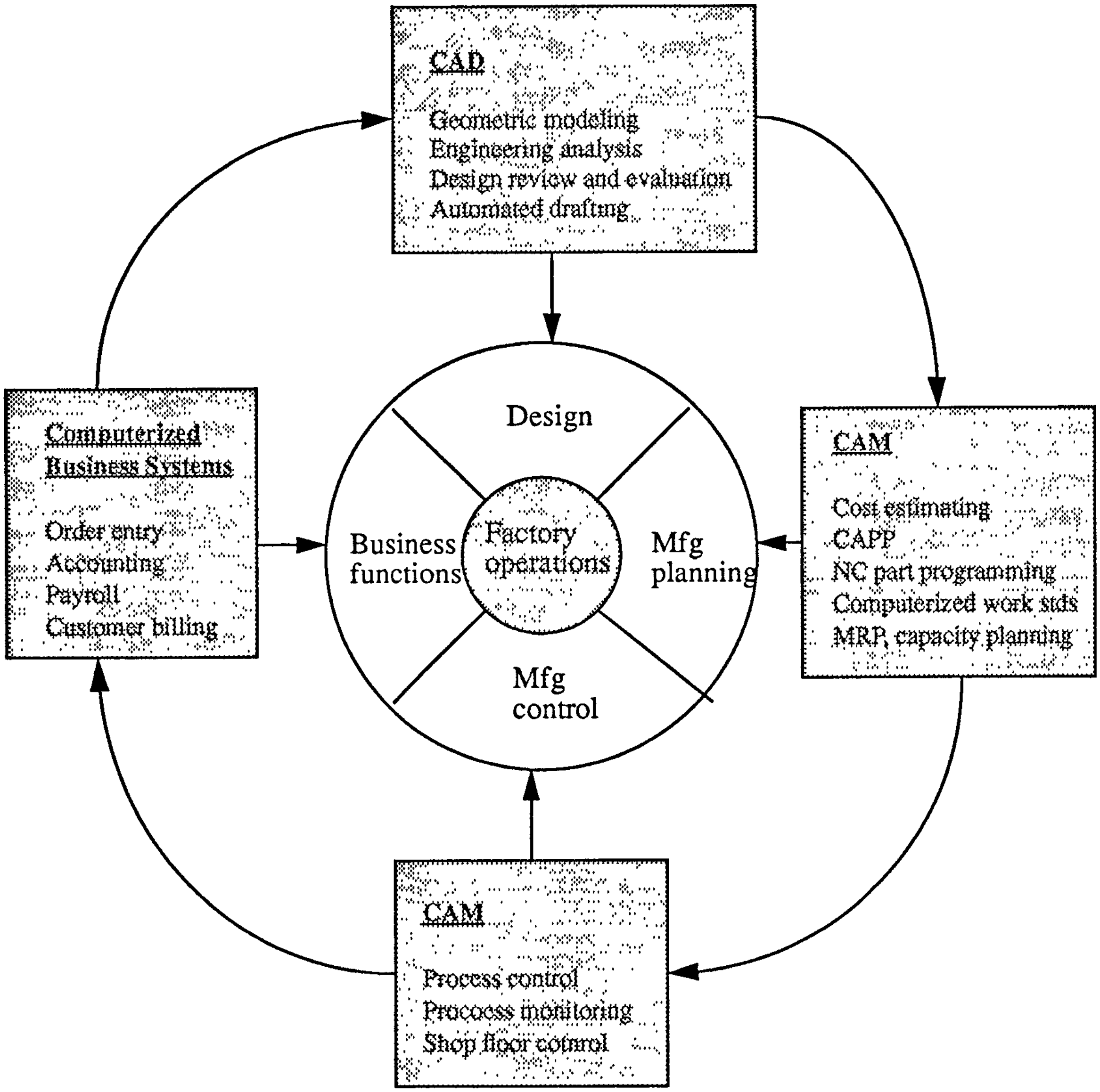


Fig 4.2 Computerized Elements of a CIM System

to an absolute minimum to become an efficient small lot producer.

5. *Maintain high process reliability with zero down time.*

By monitoring machine running time, parts produced and other conditions on the shop floor, and integrating this with a preventative maintenance system, seek to achieve zero down time.

6. *High product repeatability with zero defects.*

All products produced must be within specifications. Since machines would be expected to operate 24 hours a day, seven days a week, high product reliability would be mandatory since there would be no operators to shut the line down should specifications be exceeded.

7. *Minimum data handling resulting in zero data errors.*

Data input by bar code reader is much more reliable than manual key entry of data. Even greater reduction of errors can be achieved where data is collected from sensors mounted on machines, thus enabling data to go directly into the computerized system without any data handling whatsoever.

8. *Development of distributed intelligence that enables zero-manned operations.*

This goal will allow machines to operate 24 hours a day, seven days a week, thereby reducing capital investment and increasing machine utilization.

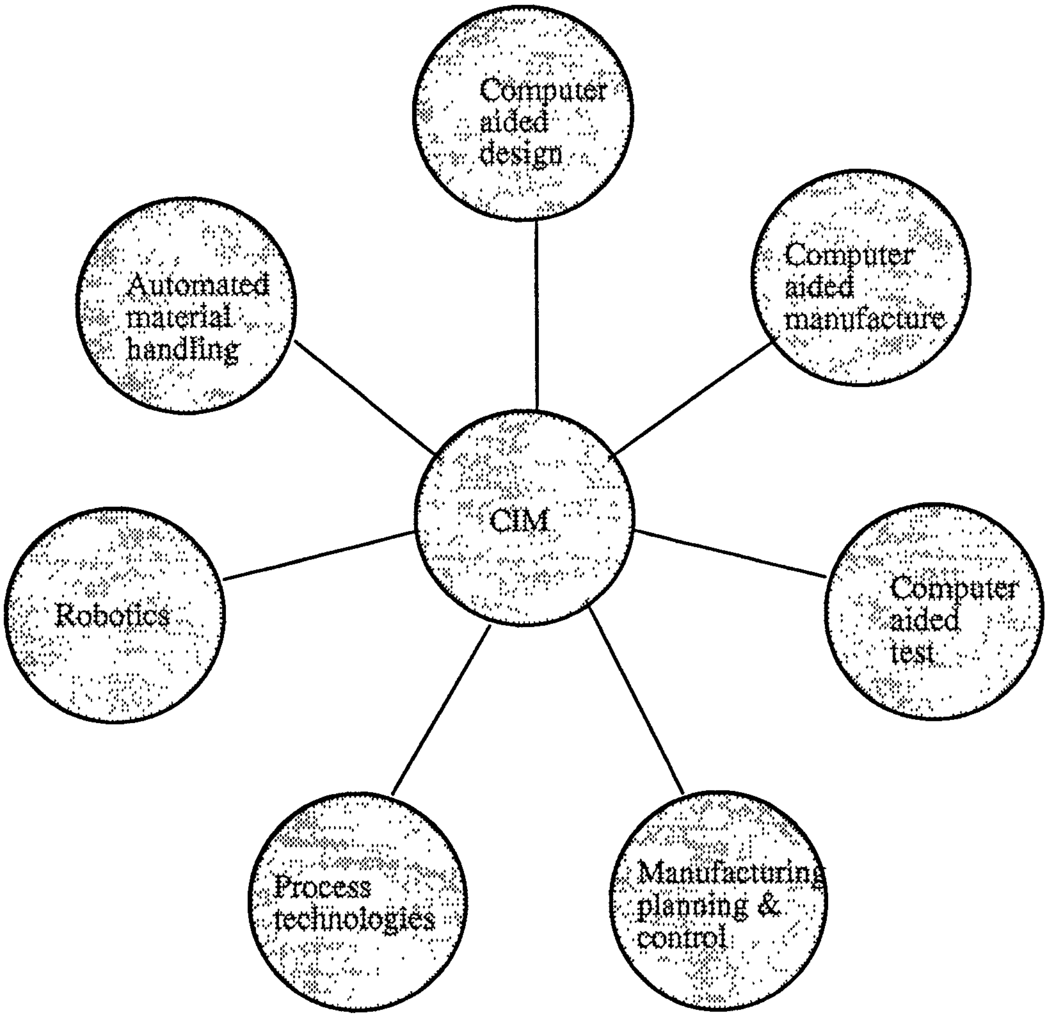


Fig 4.3 The Enabling Technologies of CIM

4.2 The role of shop floor CIM

Shop-floor CIM plays a key role in successful automation. CIM adds value to products by giving manufacturers information they need to run their processes more effectively. A shop-floor CIM system enables parameter tracking so manufacturers can avoid rejects and accurately analyze quality results. The system also provides information that allows zeroing in problems, thereby permitting incremental improvements.

Because manufacturing plants meet their output and quality requirements by making products better, this is where companies should be first concentrating their effort, rather than primarily on central computer systems technology, insistence on standards, or developing software in-house. In today's competitive environment, manufacturers need to implement computer systems that provide solutions to their true production goals--goals stated in terms such as six-sigma quality, improved mean time between failures, reduced mean time to repair, and getting new products to market faster. Shop-floor CIM requirements to support these goals often include the following:

1.Communication to and from plant devices automatically collection information from automation machinery and providing real-time status information to those who need it.

2. Machine monitoring, keeping operators aware of the operating conditions of production equipment and the

causes of problems. Monitoring includes warning operators of impending failure so corrective action can be taken before serious problems occur.

3. Production tracking, giving feed back about quantities produced, production yields, operating performance and quality problems. Such tracking is often linked to plant host systems for tight coordination with MRP and production scheduling systems.

4. Access to process information, delivering important decision criteria and operating instructions to shop floor and management personnel. A real-time system can provide up-to-the minute information to avoid delays and mistakes.

5. Statistical tools, increasing production quality through proven techniques like real-time SPC to prevent part defects, as well as through a variety of tools to help plant engineers make operating improvements by analyzing detailed production information.

6. Trend analysis, providing additional information on product, process, or machine-related factors that affect production quality and machine use.

7. Integrated system-enabling consistent access to this range of functions to this range of functions through a simple user interface. Individual application modules create confusion unless they are seamlessly integrated as part of an overall application solution. Computer

systems for manufacturing must be user-friendly and easy to support.

Each plant begins the CIM process with its own list of similar requirements. Presented in much more detail, they provide a blueprint for the required shop-floor CIM system.

CHAPTER 5

SHOP FLOOR CONTROL - FIRST STEP TO INTEGRATION

5.1 Introduction

The implementation of a shop floor planning and control system is a prerequisite to establishing an effective Computer Integrated Manufacturing System. The efforts to develop and implement CIM systems frequently focus on the integration of engineering, design and other "high tech" systems into the total manufacturing process--while ignoring the shop floor. The shop floor is "where it happens" in manufacturing.

Implementation of a shop floor planning and control (SFC) system is typically the most time consuming and frustrating element of developing a corporate CIM system; however, effectively implemented, it can result in the greatest pay back. Implementation typically requires training shop personnel, establishing procedures and disciplines, and, perhaps, modifying the organization. The result of this effort is a thorough understanding for the operation of the shop floor-- which can lead to significant improvements in productivity, quality and manufacturing responsiveness.

The goal of an SFC system is to ensure that manufacturing's major resources or investments (i.e., manpower, machinery and material) are effectively utilized.

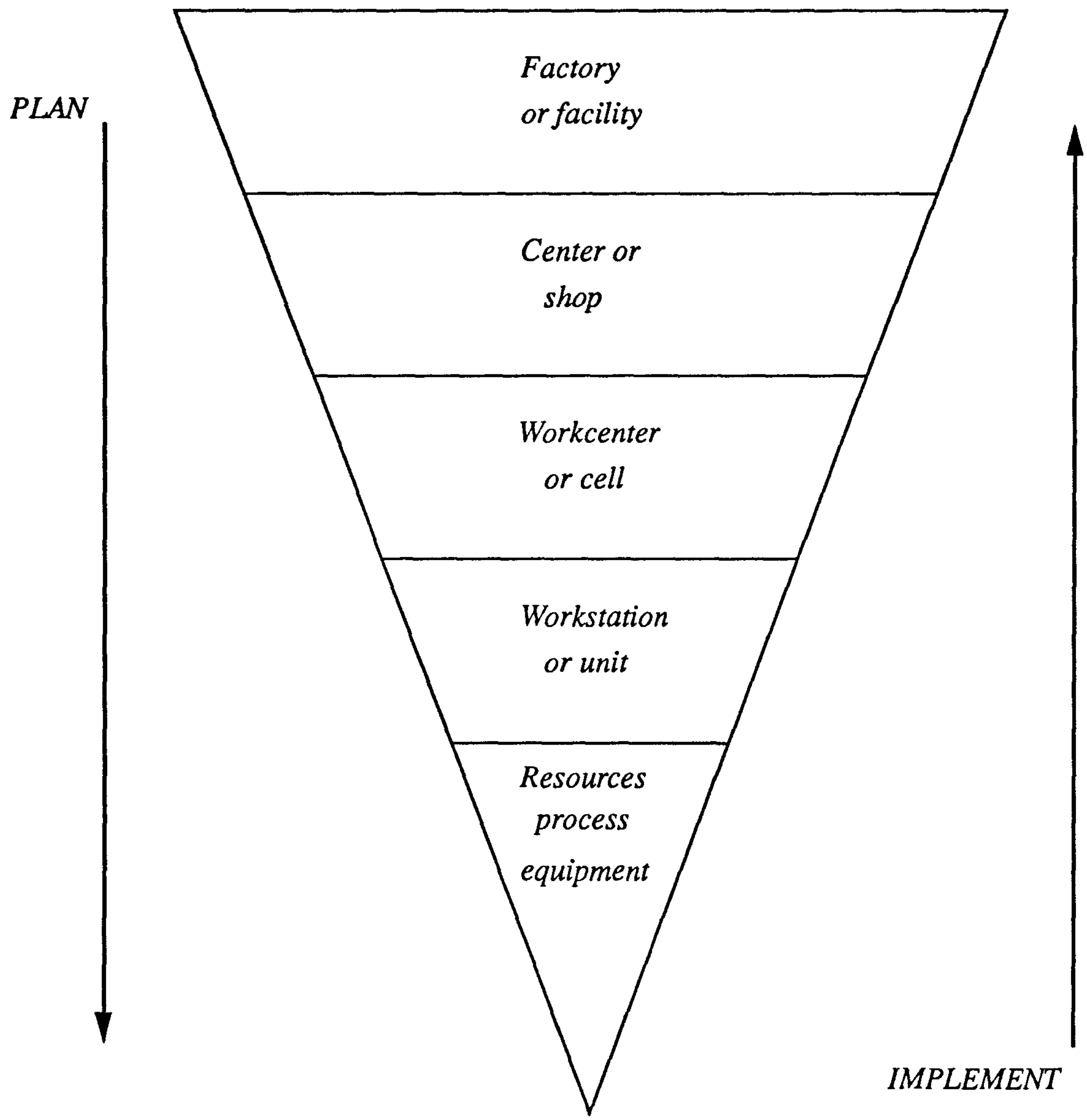


Fig. 5.1 CIM Planning and Implementation

5.2 The Need for Integrated Manufacturing Control

Traditionally, the shop floor has received the least attention in the implementation of CIM systems. Just-In-Time or Zero Inventory programs require concentrating on the shop floor and successfully executing the "basics"--solid planning and effective control.

Manufacturing control requires computerized systems that involve bills of materials, material requirements, machine loads, and scheduling of shop orders, etc.

This in turn involves the devilment of controls over sequencing of shop orders, routing of orders, and establishment of order priorities.

Feedback of activities on shop floor is achieved through various methods of shop order reporting and backlog conditions of machine tools, either individually or within work centers. In addition , the movement of products from one machining center to another requires control and feedback on materials handling activities within the factory.

5.3 Shop Floor Planning And Control

Planning and control at any level within a manufacturing operation involves:

1.Determining the goals to be achieved.

2.Developing the best plan for achieving those goals.

3.Executing the plan.

4. Feeding back the results for measurement and if required, adjusting the goals or changing the plan.

A complete planning and control system requires "closing the loop"-- beginning with planning, continuing with execution of the plan and feedback, and then re - planning.

Since the manufacturing environment is dynamic, the planning process is continuous and iterative. Each perturbation on the shop floor can result in a change to the plan; each change to the plan embodies a greater understanding of the shop floor.

Manufacturing planning occurs at three levels:

1. **Long range,** high level planning usually consisting of 5-year strategic business plan and a 1 - year operating plan. Long range planning results in general decisions such as the products to be produced and major investments to be made(eg,factories & machinery). This level of planning is based almost exclusively upon marketing forecasts.

2. **Mid range,** intermediate level planning usually comprising detailed production, financial and marketing plans derived from the 1 year operating plan. Intermediate planning results in detailed goals for production including product shipping plans.

3. **Short range,** low level planning usually consisting of highly specific plans such as production or purchasing schedules. Low level planning results in

detailed plans which can be executed on the shop floor.

Shop floor planning and control begins at the highest level of corporate planning and evolves into greater and greater detail at each successive level.

An SFC system integrates management's production goals with the capabilities and limitations of the manufacturing plant. It establishes top-down and bottom-up links to the manufacturing operation to communicate plans and receive feedback on the execution of these plans.

5.3.1 Shop Floor Planning And Control System Elements

Figure 5.2 illustrates the manufacturing planning and control process and the primary elements of a shop floor planning and control system.

The elements of a shop floor planning and control system can be divided into three categories:

1. **Planning**--which support creation of the plan and communication to the shop floor ; these include Master Scheduling, Material Requirements Planning (MRP), Capacity Requirements Planning(CRP),and Input/Output (I/O) Planning.
2. **Execution**-- which carry out the plan; including Inventory Control, Production Control, and Shop Floor Control.

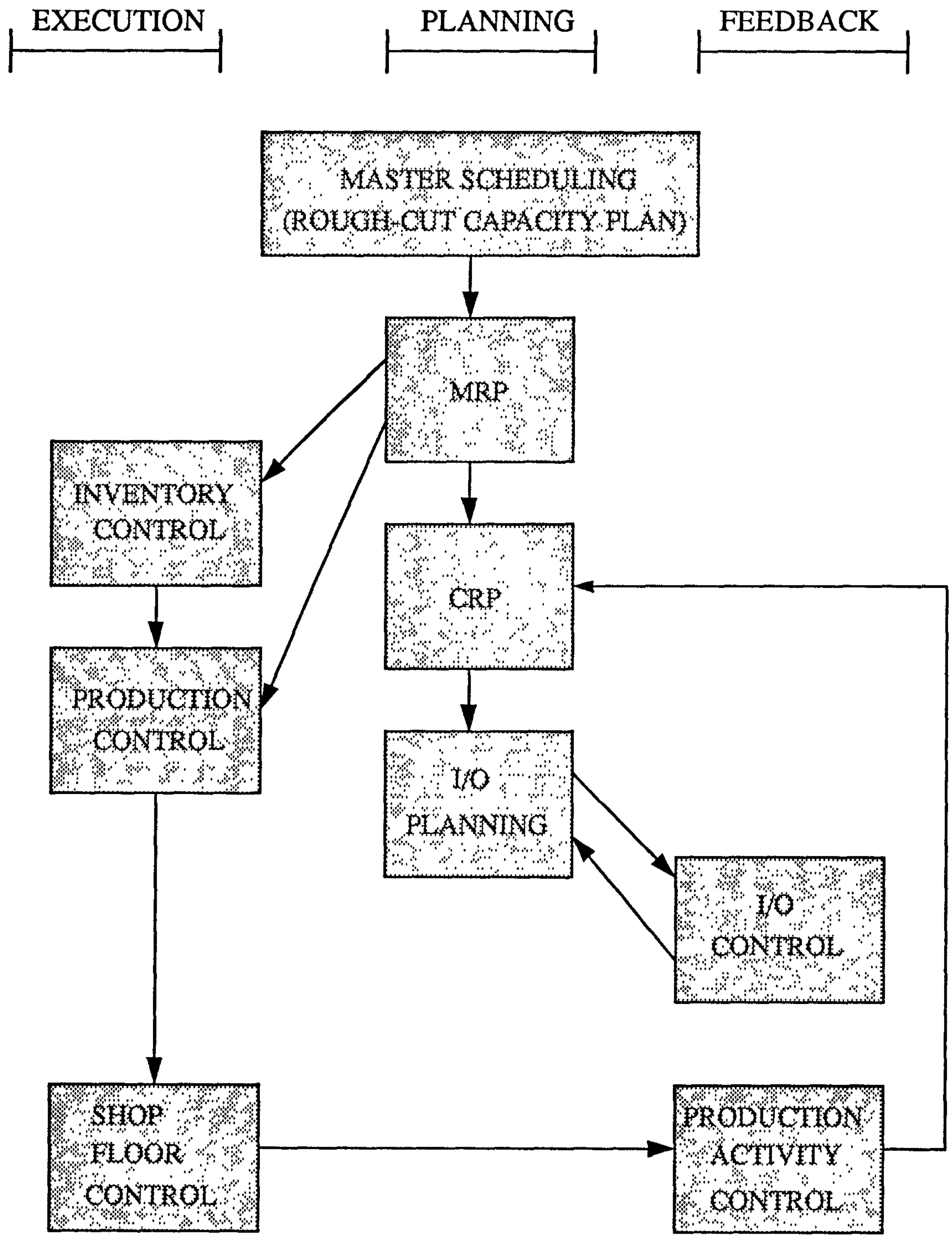


Fig. 5.2 The Manufacturing Planning and Control Process

3. Feedback-- which report the results of the execution of the plan; including Production Activity Control, and Input / Output Control.

Progression from top to bottom in figure 5.2 corresponds to a progression through time; elements near the top represent future planning activities, which those near the bottom near term activities. Master Scheduling activities should at a minimum extend beyond the cumulative lead time for the product being planned, unless an emergency situation is encountered (additions to the Master Schedule within the cumulative lead time will result in production or purchasing requirements with less than normal lead times; changes may affect production or purchasing activities already in progress). MRP and CRP provide recommendations for immediate actions to be taken and reference information for future trends. I/O Planning and Shop Floor control center on the immediate scheduling of shop orders and work centers.

The diversity of terminology found in manufacturing may result in a variety of names for those elements (e.g., a Work Center Control System, Production Control or Production Activity Control System, Routing or Shop Floor System, Capacity Planning System); each, however, will carry out the functions described in the following subsections.

5.3.1.1 Master Scheduling

The Shop Floor planning process begins with the entry of management production goals into a Master Schedule. The Master Schedule is a statement of the delivery schedule(quantities and dates) for the company's products. The Master Schedule may also contain explicit production plans for key component parts or component parts produced in work centers with limited resources.

The Master Schedule is evaluated for "achievability" using Rough-Cut Capacity Planning (RCCP). RCCP involves creating a limited Capacity Requirements Plan for critical resources (which may be available production time in a key work center, or a variety of other measures including dollars of inventory allowed, floor space available for finished products or availability of key people--e.g., for set-ups).

5.3.1.2 Material Requirements Planning

The shop floor planning process continues with the generation of a Material Requirements Plan. This plan identifies the quantity parts and materials (with associated need dates) which must be either manufactured or purchased to satisfy the Master Schedule (fig. 5.3). MRP ensures that parts and materials are available when needed, to satisfy product shipping plans and component production requirements.

Bill of Materials (BOM)

The dependent nature of material requirements is shown by the Bill Of Materials, also known as a Product Structure or

Item: ____________________

Order quantity: ______________________

Lead time: ___________________________

Safety stock: _________________________

WEEKS	0	1	2	3	4	5	6	7
Gross Requirements								
Schedules Receipts								
On Hand								
Net Requirements								
Planned Order Releases								

Fig 5.3 Material Requirements Plan

Assembly Parts List. It describes how a product is made from its component parts and assemblies, as shown in figure 5.4.

Level Coding

Each Bill Of Materials is assigned a level code according to lineage from the end product.

Lead Times

The time between issuing a purchase order and receiving the material from a vendor is the lead time.

A Manufacturing Lead Time (MLT) is the total time required to process a given product through the plant.

$$MLT = Tsu + Q*To + Tno$$

where,

MLT	is the Manufacturing Lead Time
Tsu	is the set up time
To	is the time per operation at a given machine
Q	is the number of units in a batch
Tno	is the non production time on the same machine

5.3.1.3 Inventory And Production Control

Inventory Control and Production Control execute the Material Requirements Plan (MRP). The result is inventory

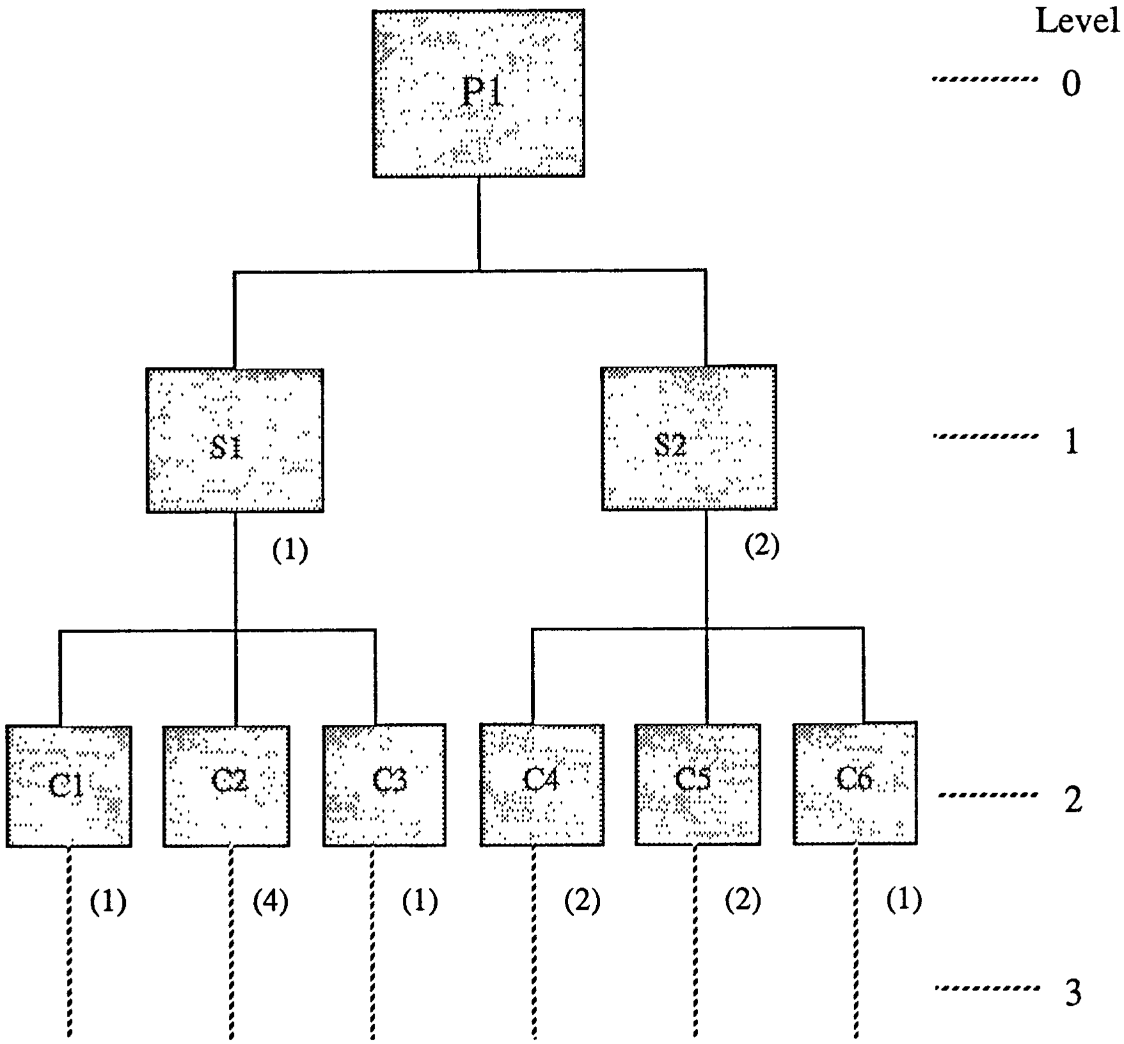


Fig 5.4 Bill of Materials

available (i.e,. in warehouses) or planned to be available (i.e., being produced on open shop orders) to support manufacturing.

Economic Order Quantity (EOQ)

The size of an order that minimizes the total inventory cost is known as the economic order quantity, EOQ, which can be calculated as ,

$$Q = ((2*O*D)/(H+iP))1/2$$

where,

Q is the economic order quantity

O is the cost per order

D is the annual demand

H is the holding cost

iP is the interest charge per unit per year

Economic Production Quantity (EPQ)

When the items are expanded as they are produced, then EOQ equation becomes,

$$Q = ((2*O*D)/(H+iP)(1-(D/M)))1/2$$

where,

M is the annual manufacturing rate.

5.3.1.4 Capacity Requirements Planning

Capacity Requirements Planning generates a complete, detailed view of the total time required in each of the plant's work centers to carry out the production requirements described by MRP. These time requirements are based upon standard run and set-up times entailed in the routines for each manufactured part.

5.3.1.5 Shop Floor Control

Shop floor control comprises two principal components: the scheduling of shop orders through each work center identified in the manufacturing routing and the prioritization of work orders to reflect emergency or other "rush" conditions. Shop orders are created to satisfy the Material Requirements Plan and are assigned a shop routing. This routing may be either the standard routing for the part or an alternate routing, which may be used for a special order or to avoid an out-of-production machine center. Based upon this routing and the quantity of parts being produced on the shop order, appropriate due dates for each required activity (e.g., arrival at each work center, start of set-up, move to the next work center) are computed.

At the time a shop order is created or later during the production process, it may be prioritized to indicate a need to rush its completion. Prioritization usually results in a compression of queue time (i.e., expected waiting time upon arrival at a work center), reflecting a desire to expedite the order through the work center.

These two activities result in a plan for the processing of each shop order on the shop floor.

5.3.1.6 Production Activity Control

Production Activity Control tracks and reports the manufacturing effort applied to each shop order as it moves from work center to work center on the shop floor. This includes reporting completed quantities and quantities scrapped during set-up or inspection.

Each work center is supplied with a dispatch list (a list of shop orders currently in the work center or due into the work center) for jockeying of orders onto available machines.

5.3.1.7 Input/Output Planning

Capacity Requirements Planning assumes a constant available capacity in each work center and ignores any existing queues of shop orders. Input/Output Planning provides the mechanism to fine tune CRP to reflect planned overtime to, for example, reduce queues or increase production rates.

I/O Planning also establishes a measure used to determine whether or not each work center is executing the shop floor plan. Quite simply, this measure is the number of standard hours of work scheduled to be performed in the work center.

5.3.1.8 Input/Output Control

Input/Output Control reports whether the I/O Plan has been successfully carried out in each work center--i.e., whether the work scheduled to be performed has indeed been completed. It also shows the trend of queue sizes for each work center and the shop as a whole, which may point to problems (e.g., increasing queues may indicate a production bottleneck).

5.4 Production Goals Vs. Manufacturing Capabilities

One of the most difficult efforts in developing a reasonable shop floor plan is to reconcile management's production goals with the real capabilities or limitations of the manufacturing operation. Management, especially top management, will try to set the goal as high (optimistic) as possible. Manufacturing, on the other hand, will try to lower the goal as far as possible (pessimistic)--to establish a cushion (or a better chance of being a hero if the original goal is actually met).

Both management and manufacturing must be open to negotiation. Setting goals which are unattainable results in schedules which are continually missed; goals which are too low waste manufacturing resources.

Establishing an effective plan also requires asking some very difficult (and politically dangerous) questions. Many parts which are produced in-house (rather than being procured from an outside vendor) are produced due to tradition--periodically the question should be asked if the parts can be more economically purchased rather than manufactured. And the reverse question should also be asked--does available production capacity suggest moving a purchased item in house.

An effective shop floor planning process considers both the "internal" factory and the "external" factory--vendors--and evaluates the economic advantages of using each.

5.5 Shop Floor Planning

Shop floor planning begins with a long term estimate of required manufacturing capacity. This is refined into a short term, detailed plan as these requirements are analyzed at each lower planning level. Shop floor planning is the start of the planning loop; it requires both a top-down communication of the plan to the shop and bottom-up feedback on the success in executing the plan.

5.5.1 Capacity Requirements Planning

The heart of CRP is the Capacity Requirements Planning Report. This report displays the total time required in each work center to meet the Material Requirement Plan (and hence the master schedule). A sample report is displayed in fig. 5.5. The rows on the capacity requirements planning report display the following information:

Planned load -- the total number of hours require for planned orders (suggested by the Material Requirements Plan) for the calender period.

Open load--the total number of hours required for all open shop orders for the calender period.

CAPACTIY REQUIREMENTS PLANNING REPORT

WORK CENTER: 16B

	PASTDUE	82-30	82-31	82-32	82-33	82-34	82-35
PLANNED LOAD	20	106	101	82	97	99	115
OPEN LOAD			8	28	20	50	40
TOTAL LOAD	20	106	109	110	117	149	155
CAPACITY	0	110	110	110	110	90	110
OVER/UNDER	-20	4	1	0	-7	-59	-45

Fig. 5.5 Cacpacity Requirements Planning Report

(Completed operations within a shop order are excluded.)

Total load--the sum of the planned and open loads.

Capacity--the work center's total available capacity in standard hours for the calender period.

Over/Under-- the difference between the work center's total load and the available capacity for the calendar period. A negative number indicates an overload; a positive number indicates that a greater load can be processed.

The CRP report is used by a production planner to analyze the loads being projected for each work center. A requirement significantly over or under the available capacity signals that action must be taken (e.g., re - scheduling an open shop order).

For effective capacity planning, resources need to be defined functionally, not organizationally. For example, a work center would be all drill presses having a particular capacity (i.e.., able to accommodate the same work) rather than the drill press department. As capacity planning calculations are for a work center all machines within the work center must be capable of handling the same jobs (ideally in the same standard hours).

Work stations or machines can be defined within a work center for further differentiation of available resources; however, each must be interchangeable for processing. The number of work stations in a work center should be equivalent to the number of shop orders which can be processed simultaneously.

Different work centers may be identified as alternative processing locations(e.g., a drill press with a 2 inch chuck capacity may be an alternative for a 1/2 inch capacity press, but not the reverse). Alternative work centers should not be used in capacity calculations.

A variety of methods may be used to establish the capacity of a work center (e.g., efficiency or utilization factors, demonstrated capacity). Simple methods should be used initially; once valid capacity measurements for a work center have been established, more complex methods may be adopted.

Capacity planning must be done for all resources in manufacturing. Inspection stations, inspectors and special test equipment are frequently excluded as not really being part of manufacturing--and immediately become bottlenecks. Each of these potentially constricting resources should be defined as a work center and included in CRP.

5.5.2 Queue Planning

Queues perform a vital function in manufacturing--e.g., they provide a cushion for unpredictability in complex manufacturing processes. Queues can also be used as a measure of success in executing a shop floor plan. Stable queues, for example, indicate that the plan is being carried out properly; decreasing queues are certainly desirable if the plan is to reduce queues.

Queue planning is used to establish the measuring point for the queue in each work center. A sample Queue Planning 'Report is displayed in figure 5.6.

The following information is displayed on the Queue Planning Report:

Actual Queue -- the total number of standard hours already in the work center waiting to be done.

Pln Std Inp (Planned Standard Input) -- the total number of standard hours projected to arrive at the work center based upon Capacity Requirements Planning calculations.

Pln Std Out(Planned Standard Output) -- the total number of standard hours available for processing for the work center.

Pln Cum Dif (Planned Cumulative Difference) -- the resulting queue after applying Planned Input and Planned Output to the beginning queue.

Plan Queue --the planned number of hours that material arriving at the work center will wait in queue.

Variance -- the difference between the Planned Cumulative Difference and the Planned Queue. A negative number indicates operation below the planned queue; a positive number, above the planned queue.

QUEUE PLANNING REPORT

WORK CENTER: A6 ACTUAL QUEUE: 120 HRS.

	82-35	82-36	82-37	82-38	82-39	82-40	82-41	82-42
PLN STD INP:	500	550	550	602	431	663	520	519
PLN STD OUT:	550	550	550	550	550	550	550	550
PLN CUM DIF:	70	70	70	122	1	114	84	53
PLAN QUEUE:	200	200	200	200	200	200	200	200
VARIANCE:	-130	-130	-130	-78	-199	-86	-116	-147

Fig. 5.6 Queue Planning Report

5.5.3 Queue Time

Queue time for each machine can be calculated as,

$$Tq = Ha/Hs$$

where,

Tq is the Current Queue time decimal days for each operation

Ha is current actual department load in standard hours

Hs is average standard hours produced per day

5.5.4 Queuing Formulas

Following are the single phase queuing formulas for single and multiple channels:

$$P_n = \left(1 - \frac{\lambda}{\mu}\right)\left(\frac{\lambda}{\mu}\right)^n$$

$$P_0 = 1 - \frac{\lambda}{\mu}$$

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

$$L = \frac{\lambda}{\mu - \lambda} = L_q + \frac{\lambda}{\mu}$$

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{L_q}{\lambda}$$

$$W = \frac{1}{\mu - \lambda} = W_q + \frac{1}{\mu} = \frac{L}{\lambda}$$

$$P_0 = \frac{1}{\left[\sum_{n=0}^{N-1} \frac{(\lambda/\mu)_n}{n!}\right] + \left[\frac{(\lambda/\mu)_N}{N!\,(1 - \lambda/\mu N)}\right]}$$

$$L_q = \frac{(\lambda/\mu)^{N+1}}{(N-1)!(N - \lambda/\mu)^2} \times P_0$$

$$L = L_q + \frac{\lambda}{\mu}$$

$$W_q = \frac{(\lambda/\mu)^{N+1}}{\lambda(N-1)!(N - \lambda/\mu)^2} \times P_0 = \frac{L_q}{\lambda}$$

$$W = W_q + \frac{1}{\mu} = \frac{L}{\lambda}$$

where,

Pn is the probability of ' n ' parts being processed or waiting to be processed

Po is the probability that the machine is idle (no part in the queue, n = 0)

Lq is the mean number of parts in the queue

L is the mean number of parts in the system (shop floor)

Wq is the mean waiting time for a part before being processed

W is the mean time in the system

λ is the average number of arrivals per unit time

μ is the average number of processing that each channel can perform per unit time

The single channel formulas are modified for constant processing times to :

$$L_q = \frac{\lambda^2}{2\mu(\mu - \lambda)}$$

and

$$W_q = \frac{\lambda}{2\mu(\mu - \lambda)}$$

5.6 Shop Floor Scheduling

Shop floor scheduling techniques makes easier to provide the allocated resources at the right time. Co-ordination of operations has been a major concern in production planning. Scheduling techniques assist effective thinking by sponsoring a step by step routine for co-ordination work assignments and resource utilization with shop floor objectives.

5.6.1 Network Scheduling

Network scheduling is a graphical approach to the sequencing and co-ordination of shop floor activities necessary to complete a production task economically and on time (fig. 5.7). The most celebrated versions of network scheduling

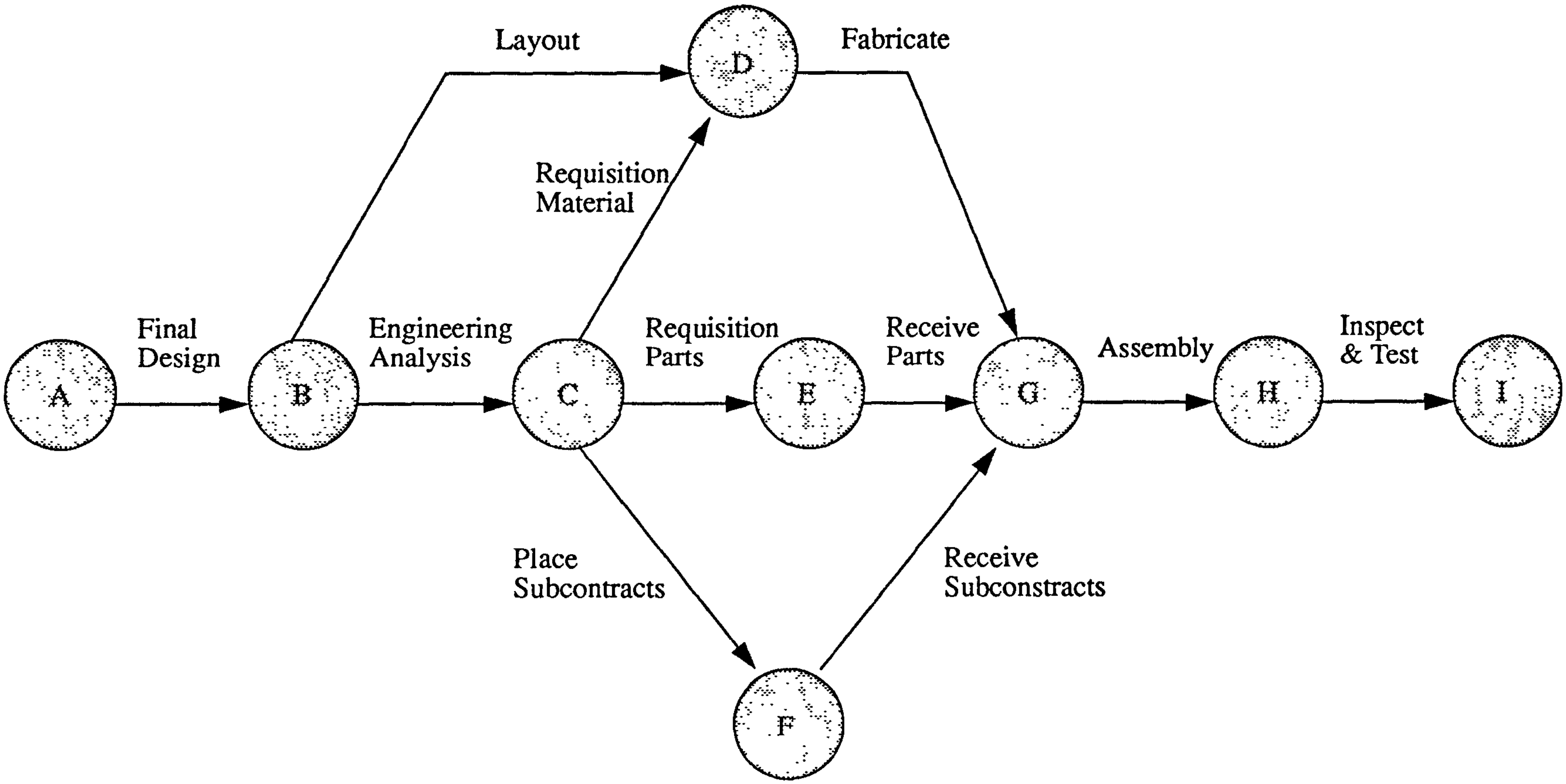


Fig. 5.7 Network Scheduling

are the critical path method (CPM) and the Program Evaluation and Review Technique (PERT).

5.6.1.1 Critical Path Method (CPM)

The first step in CPM application is to breakdown the task into its component operations to form a complete list of essential activities. An activity is a time consuming task with distinct beginning and end points called events. As the activity list develops, an order of completion is established by a restriction list, a statement of prerequisite--post requisite relationships for each activities. From the two lists evolves a network drawn according to conventions, in which arrows representing activities connect nodes showing the sequence of events. Dummy arrows are included to allow the distinctive nodal numbering for computer applications and to show certain events restrictions.

5.6.1.2 Program Evaluation and Review Technique (PERT)

A single activity duration is estimated in the deterministic approach: a range of time estimates is used in the statistical PERT approach. With PERT, expected times (te) result from the formula,

$$te = (a+4m+b)/6$$

where 'a' and 'b' are, respectively, optimistic and pessimistic estimates and 'm' is the most likely duration.

With activity durations estimated by either method, boundary times are calculated for all network activities to determine the float available for non-critical activities and the chain of activities that sets the total task duration-the critical path.

5.6.2 Machine Utilization

Time and money are the parameters by which machine performance and maintenance policies are measured. Time is the criterion for utilization, and money is the yard stick for investment comparisons.

5.6.3 Sequencing

Sequencing procedures establish the minimum time route for processing through work stations. Convenient methods are available for two (products) * n (stations) and n * two patterns of process layouts. The sequences can be displayed on time charts. Fig. 5.8 represents a manufacturing operation sequence required on the product. The duration of each operation is shown below the arrow.

5.6.4 Line Balancing

Line balancing procedures are used to sequence ' n ' operations for one product in product layouts. A network is drawn to describe the problem. A minimum cycle time and number of work stations are set by the largest operation in the line. Then operations are assigned to workstations in

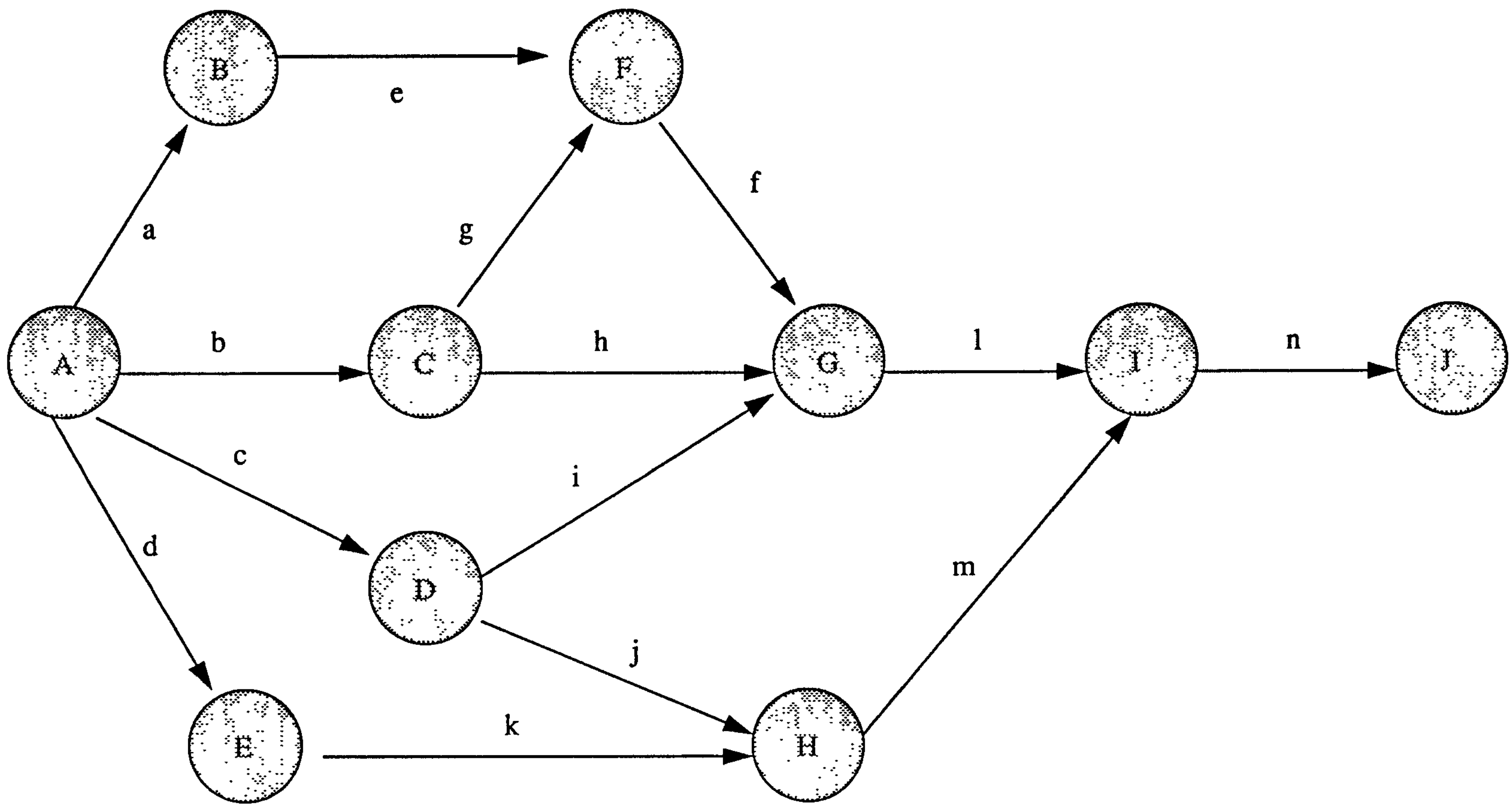


Fig. 5.8 Sequence of Operations Required to Complete a Product

conformance to the network's sequence restrictions, with the objective of minimizing idle time and maximizing the proficiency.

$$n = T/t$$

$$E = T/(tc*n)$$

where,

n is the minimum number of work stations

T is the sum of activity times

t is the largest activity times

tc is the cycle time.

5.7 SHOP FLOOR CONTROL

Once a shop floor plan has been approved and set in motion, shop floor control is required to close the loop -- i.e., to ensure its execution and feed the results back to the planning function.

5.7.1 Input/Output Tracking

Input/Output Tracking measures the number of hours of work actually received and completed by a work center for comparison to the I/O Plan.

A sample Input/Output Tracking Review Report is displayed in Figure 5.9.

The Input/Output Tracking Report contains the following information:

Work Center input rows:

I/O TRACKING REVIEW REPORT

PLANNER: KC　　WS-ID: WS-001　　DESC: SANDING

DEPT: DEPT-01　　ACT-QUEUE:　　1.000

	PAST WKS		CURR		FUTURE WKS	
	83-005	**83-006**	**83-007**	**83-008**	**83-009**	**83-010**
PLN STD INP:	525	550	575	550	600	625
ACT STD INP:	500	550	600	550		
CUM DEV:	-25	-25	0	0		
PLN STD OUT:	550	550	550	550	550	550
ACT STD OUT:	580	420	600	540		
CUM DEV:	30	-100	-50	-60		
ACT STD INP:	500	550	600	550		
ACT STD OUT:	580	420	600	540		
CUM QUE CHG:	-80	50	50	60		

Fig. 5.9 Input/Output Tracking Report

Pln Std Inp (Planned Standard Input) -- the number of standard hours that were/are planned to arrive at the work center for the calendar period.

Act Std Inp (Actual Standard Input) -- the number of standard hours that arrived at the work center during the calendar period.

Cum Dev (Cumulative Deviation) -- The cumulative difference between the planned and actual standard input.

Work center output rows:

Pln Std Out (Planned Standard Output) -- the planned capacity in standard hours for the work center.

Act Std Out (Actual Standard Output) -- the number of standard hours completed in the work center during the calendar period.

Cum Dev (Cumulative Deviation) -- the cumulative difference between the planned and actual standard output.

Comparison rows:

Act Std Inp -- as above.

Act Std Out -- as above.

Cum Que Chg (Cumulative Queue Change) -- the cumulative difference between the actual standard input and output.

5.7.2 Input / Output Factor Review

Input/o utput data can also be used to measure the performance of a work center through efficiency, utilization or load factors. A sample I/O Factor Review Report is displayed in Fig. 5.10. The rows on the Input/Output Factor Review Report display:

Clock Hours -- the working clock hours for the work center.

Downtime -- the time the machine is not productive due to machine failure or maintenance.

Act Std Output(Actual Standard Output) the no. pieces completed extended by the standard hours per piece.

Act Cur Output (Actual Current Output) -- the actual labor recorded to accomplish the work. Efficiency and utilization columns:

Efficiency -- production efficiency for the work center; ratio of Actual Standard Output to Actual Current Output.

Utilization -- utilization of potential available work time for the work center; ratio of clock Hours less Downtime to Clock Hours.

E Times U -- estimated standard output that can be achieved by the work center; Efficiency extended by Utilization.

Load Factor -- projected performance for the work center;ratio of Actual Standard Output to clocks hours.

7.3 Queue History

The queue planning loop is closed with a review of queue

I/O FACTOR REVIEW REPORT

PLANNER:	KC	WC-ID:	WC-001	DESC:	SANDING
DEPT:	DEPT-01		CURRENT PERIOD:		83-044

	83-040	**83-041**	**83-042**	**83-043**	**TOTAL**	**YTD**	**PY**
CLOCK HOURS:	500	500	500	400	1900	5800	22000
DOWNTIME:	8	0	4	0	12	20	1280
ACT STD OUTPUT:	480	420	360	400	1660	4280	18090
ACT CUR OUTPUT:	490	380	490	410	1770	4580	16510

YEAR TO DATE:	**EFFICIENCY**	**UTILIZATION**	**E TIMES U**	**LOAD FACTOR**
LAST 4 WEEKS:	93%	99%	92%	87%
YEAR TO DATE:	93%	99%	92%	73%
PRIOR YEAR:	109%	94%	102%	82%

Fig. 5.10 Input/Output Factor Review Report

activity and trends. A sample Queue History Report is displayed in Figure 5.11. The rows on the Queue History Report display:

Pln Std Inp (Planned Standard Input) -- the number of standard hours that were planned to arrive at the work center.

Act Std Inp (Actual Standard Input) -- the number of standard hours that arrived at the work center.

Cum Dev (Cumulative Deviation)-
the cumulative difference between planned and actual input.

Pln Std Out (Planned Standard Output) -- the planned capacity of the work center in standard hours.

Act Std Out (Actual Standard Output) -- the number of standard hours completed in the work center during the calendar period.

Cum Dev (Cumulative Deviation) -- the cumulative difference between planned and actual standard output.

Cum Queue Chg (Cumulative Queue Change) -- the cumulative difference between actual standard input and actual standard output.

5.7.4 Control Action

A master production schedule consolidates information from pre production planning activities. It shows how and when products will be ready for distribution as shown in fig.

QUEUE HISTORY REPORT

WORK CENTER: A6

	82-05	82-06	82-07	82-08	82-09	82-10	82-11	82-12
PLN STD INP	500	550	550	602	431	663	520	519
ACT STD INP	550	550	550	550	550	550	550	550
CUM DEV	50	50	50	-2	117	4	34	65
PLN STD OUT	570	570	570	570	570	570	570	570
ACT STD OUT	500	600	600	580	620	550	570	550
CUM DEV	-70	-40	-10	0	50	30	30	10
ACT STD INP	550	550	550	550	550	550	550	550
ACT STD OUT	500	600	600	580	620	550	570	550
CUM QUEUE CHG	50	0	-50	-80	-150	-150	-170	-170

Fig 5.11 Queue History Report

5.12. The Dispatching function implements the operations from the master schedule. Expediting is often combined with the dispatching functions. Expediting is concerned with the flow of material and components, whereas dispatching pertains more to the flow of information. An expeditor follows the development of an order from the raw material stage to finished products.

5.7.4.1 Critical Ratios (CR)

Critical ratios are calculated to assist the scheduling of work. Job orders are given priority according to the urgency of completing them to meet promised delivery times or to maintain a desired level of supply. Lower ratios indicate greater urgency.

$$CR = \frac{\text{Time remaining before a job should be done}}{\text{Usual time required to complete the job}}$$

$$= \text{Stock Ratio/Manufacturing Ratio}$$

$$= \frac{\text{Stock on hand/order point quantity}}{\text{Remaining MLT/Total planned lead time}}$$

5.7.4.2 Productivity

Productivity is the quality or state of being productive.It

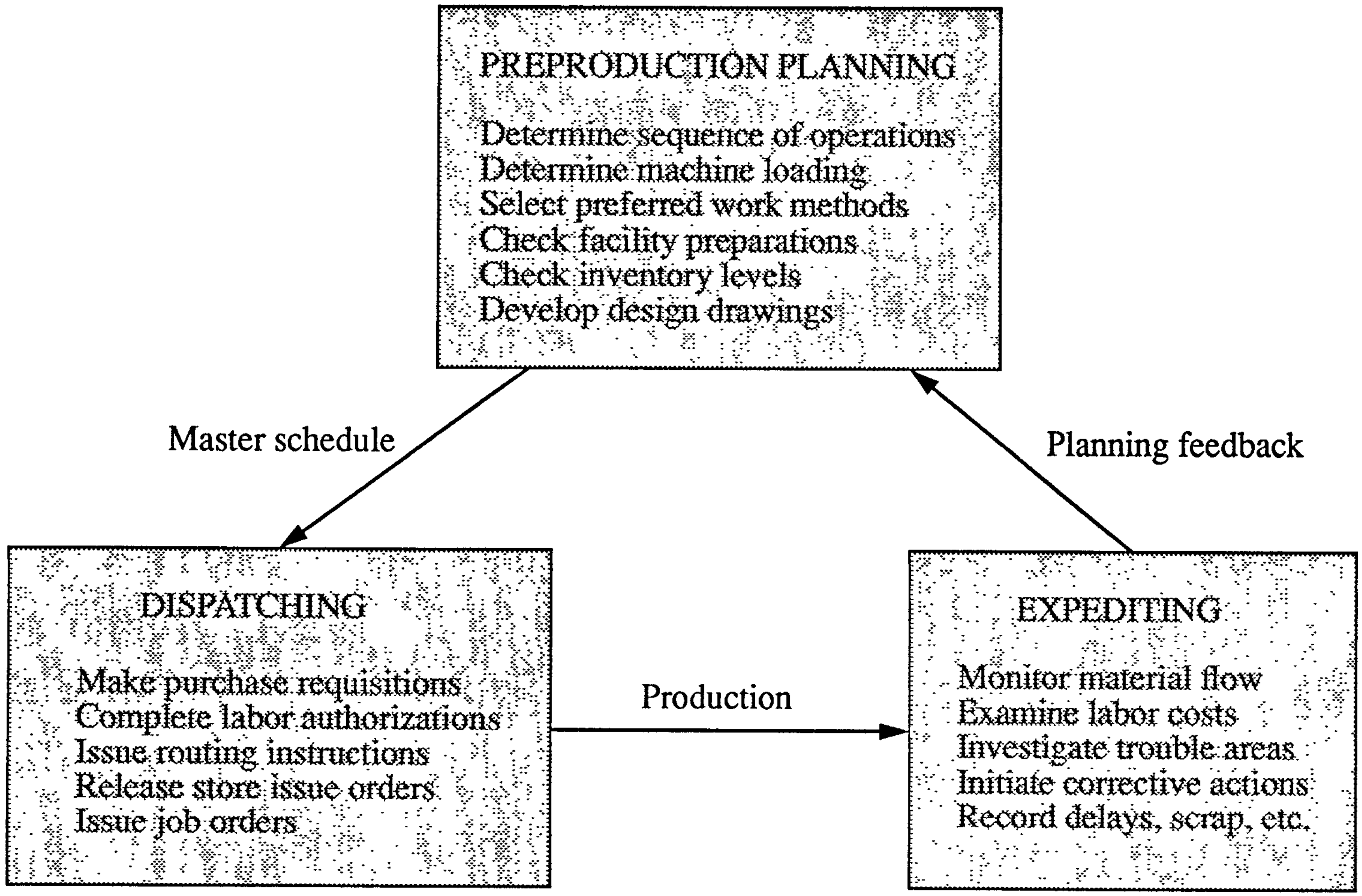


Fig 5.12 Control Activities

is a concept that guides the management of a production system and measures its success.

5.7.4.3 Productivity Ratio

The basic productivity ratio is,

$$Productivity = Output/Input$$

5.7.4.4 Total Productivity Index

Total productivity index is a single figure that expresses the efficiency of an entire organization. A macro level index can be expressed as,

$$\text{Total productivity index} = \frac{\text{Product + Service}}{\text{Labor+Materials+Energy+Capital}}$$

5.7.4.5 Factor Productivity Index

Efficiency of individual operations and effectiveness of specific capital expenditures are lost in the inclusive indexes. Factor productivity indexes are more valuable rating for the utilization efficiency of specific resources, and can be calculated as;

$$\text{Factor Productivity Index} = \frac{O2P1/\ O1P1}{I2C1/\ I1C2}$$

$$\text{Factor Productivity Index} = \frac{\text{Current Output/Base Output}}{\text{Current Input/Base Input}}$$

5.8 Shop Floor Auditing

Periodically, the shop floor should be audited to confirm the accuracy of shop floor measures. This audit is similar in nature to traditional inventory "cycle counting" (where a rotating group of parts are counted periodically to confirm the validity of inventory record keeping). In fact, this audit may include shop floor cycle counting.

5.9 SFC System And Zero Inventory

The goals we strive for in manufacturing are to schedule activities to happen "just in time" or to maintain a "zero inventory" balance. The intent of the Just-In-Time philosophy is to precisely schedule manufacturing activities, thereby eliminating delays or lags. Zero Inventory is intended to eliminate the "wasteful" excesses built into most operations to overcome deficiencies in planning and control. Both of these goals require an achievable shop floor plan and effective shop floor control which keeps the planning function synchronized with the shop floor.

To borrow from a phrase in vogue, adoption of a Just-In-Time or Zero Inventory philosophy is a step toward "excellence in manufacturing" -- an extension of effective planning and control. Implementing an SFC system sets the spring-board to a Just-In-Time or Zero Inventory program.

Many times the elements built into a CIM system are either "sophisticated" or designed to handle the "exceptions" of the plant. That is, they are either a new or currently popular concept or intended to satisfy a particular manufacturing requirement that surfaces only periodically. Successful integration of manufacturing through a computer requires successful execution of the "basics." Shop floor planning and control focuses on the real requirements of keeping a manufacturing operation flowing; it emphasizes the process of manufacturing a product.

Implementation of a shop floor planning and control system is not fast -- it requires careful planning, a deliberate course of action, and the staying power to see it through. The result is the foundation for CIM. After all, the key word in CIM is "manufacturing."

5.10 Benefits Of A Shop Floor Control System

To ensure that all elements of the control phase are being monitored properly, it is essential that an effective computerized system be installed that interfaces with the computer-based planning cycle. This set of controls should enable a user to issue shop orders, track work-in-process, maintain work center information, and analyze shortages and backlogs. Data obtained from this system should result in increased labor efficiency, better machine utilization, less downtime, and more reliable capacity planning and overtime scheduling. In essence, it can result in more complete control of the manufacturing process through greater detailed knowledge of what it will take to finish a job and what alternatives are available when there are deviations from the plan.

More specifically, this system can inform production control when orders are completed at each operation, how much has been scrapped or rejected, when an order needs to be split, and the variance between the planned hours and the actual hours it takes to finish an order. It also can display or print shop order history by part, order, or date, and examine issuers, partial completions, and receipts.

A computerized shop floor system can generate routing, manufacture bills of material, and pick lists. A shop floor control system can provide these features:

1. Maintains data instantly with on-line interactions.
2. Stores, maintains, and prints standard routing data by operation for each manufactured part.
3. Separates total manufacturing lead time into plan, build, and stock times.
4. Tracks standard run times and queue times for batch or unit processes.
5. Prints shop paperwork for picking inventory and order routing.
6. Calculates operation due and start dates using

backward scheduling.

7. Prints and displays work center status with start due date priorities.

8. Monitors work center input and output and reports work center queues to help manage shop lead times.

9. Displays time-phased work center queue and backlog versus capacity to identify capacity constraints.

10. Displays load and queue by work center.

CHAPTER 6
SIMULATION ON SHOP FLOOR

6.1 Introduction

Computer-integrated manufacturing (CIM) requires the effective coordination of all significant components of the manufacturing organization. Simulation is an analysis tool that is essential to the successful implementation of CIM as it allows manufacturing engineers to better control the interaction between shop floor components. Computer integrated manufacturing involves creating a planning, control, and process elements of the shop floor communication between shop floor components to facilitate effective material movement and material processing. This heightened level of information coordination among the individual functions allows the shop floor management, through simulation, to assess the effect of local decisions on the system as a whole. Whether it be a product design change or process planning change, a scheduling change or a material handling change, computer simulation can provide an accurate, integrated account of this change and forecast its effect on the system.

Currently, simulation concepts are actively being employed to improve engineering design, manufacturing planning, and manufacturing control activities on shop floor. Most of these applications are off-line in the sense that system data is down-loaded to the simulation environment where the evaluation is performed. Results are then presented manually to decision makers. With CIM , this entire process will be made interactive. The simulation software and the CIM data base will communicate in an on-line environment to provide more responsive and more comprehensive analyses. With CIM, powerful simulation analysis capabilities will be brought from the specialized mathematical modeling environment and made available to manufacturing engineers, designers, and operators.

6.2 Simulation Methodology

Simulation is the process of building a representation or model of the operation of a system on a digital computer, as shown in figure 6.1. This model is constructed using a description of the physical components of the system and the logic of their operation. The model then is used as a laboratory for conducting experiments that predict how the system will operate under various scenarios. Because complete operational problems can be addressed without incurring the cost of actual system experimentation; simulation turns out to be an extremely cost-effective analysis approach. For existing systems, improvements to equipment or improvements in operational strategies can be evaluated without affecting actual system operation. If a replacement system is being considered, the evaluation can be performed without destroying the existing system. For

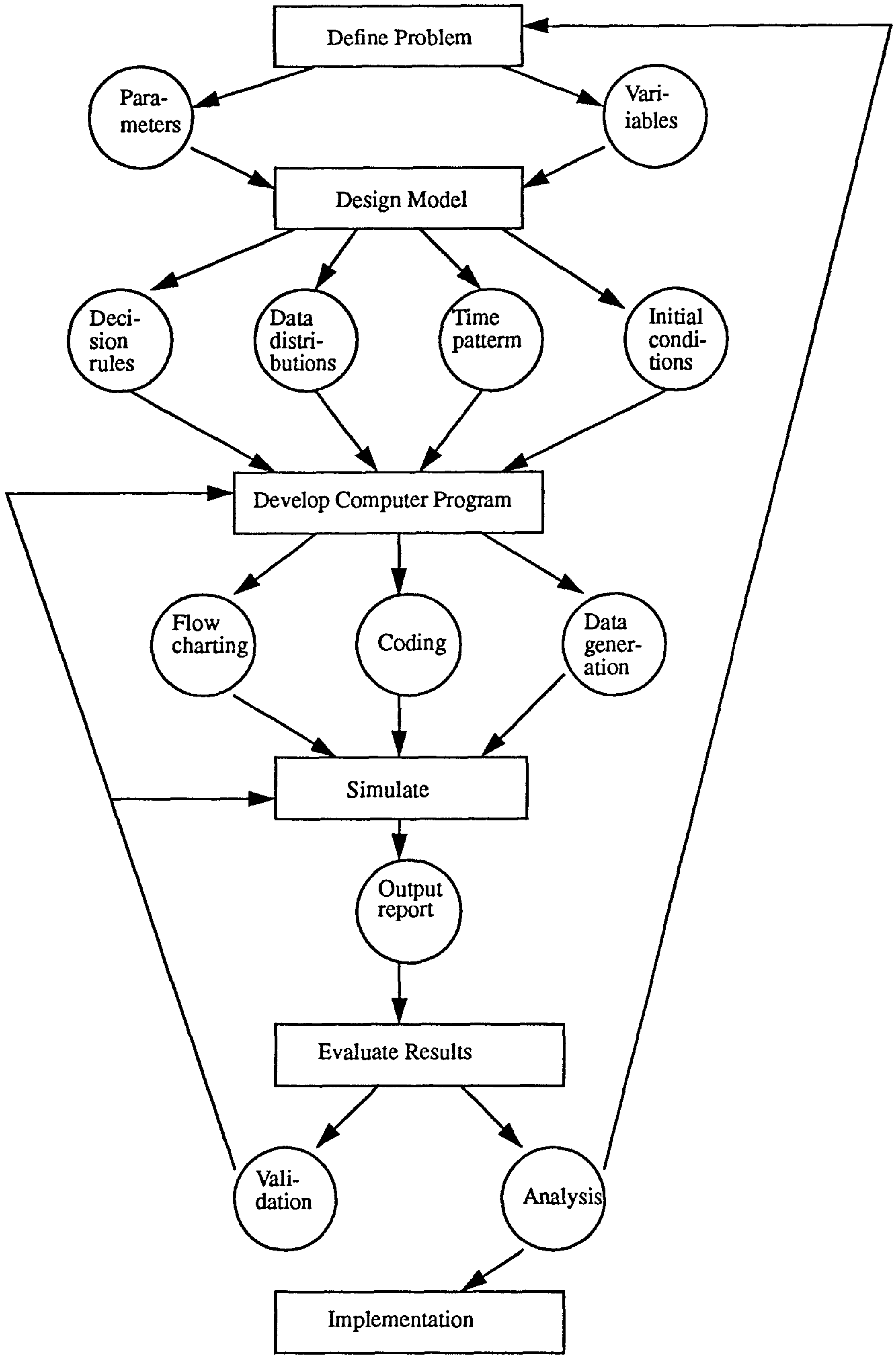


Fig 6.1 Computer Simulation Methodology

new systems, the effectiveness of a design can be evaluated before an investment is made in its construction.

With simulation, shop floor management can evaluate many different specifications for processing equipment, machine utilization, inventory buffers, material handling devices, inspection, procedures , control logic, and other equipment/ policy concerns. The most effective of these configurations can then be played against a variety of demand scenarios to test their robustness. In this manner, shop floor management can use simulation to account for the complete interactions between components and to develop effective planning alternatives and control strategies. Armed with this information, management can make more informed and more cost-effective decisions.

Simulation is effective because it can be used to predict the impact of a decision, whether that decision involves facility or operating logic upgrades, before the decision is implemented. It can be used to determine a priori how successful that decision will be. In this way, simulation is an effective decision support tool.

In normal practice, a simulation language is employed to expedite the modeling and analysis process. The language provides capabilities that are common to most simulation efforts and also forces an organization and a structured approach to the modeling activities. Examples of popular languages are GPSS, SIMAN, SLAM, SIMSCRIPT, and MAP/1.

6.3 Advantages of Simulation

Based on the implementation of several hundred simulation systems, Pritsker & Associates has identified the following five benefits of simulation:

1. **Versatile.** Computer modeling may be used to represent a wide variety of real-world systems.
2. **Flexible.** Computer models may be easily altered to represent different situations updated information.
3. **Cost effective.** Experiments using computer simulation enable the performance of a system to be reliably investigated without building the physical system.
4. **Non disruptive.** Simulation experiments permit a system to be designed , redesigned , and analyzed with out disrupting any existing system.
5. **Exhaustive.** Simulation experiments may be performed under every conceivable set of system conditions, parameters, or operating characteristics.

6.4 How Simulation helps on shop floor.

Effective shop floor planning and control requires an understanding of how a particular decision will impact the shop floor environment. This understanding can be quite difficult to grasp due to complexity of most problems in today's shop floor environment. Decision consequences can be exposed by the construction of a simulation model that describes the dynamic structure and response of the system to controlled inputs. Useful and effective models depend on sound engineering judgement, experience gained from similar shop floor systems, close examination of the system to be modeled, operating constraints, and managerial goals and policies that impact it. Since a simulation model is a representation of the actual shop floor system to be studied, it provides an understanding of system behavior while avoiding costly problems associated with building a proposed shop floor system, distributing a current system, destroying a current system.

As a diversified decision support tool, simulation may be employed to accomplish and support activities such as the following:

* **Strategic Planning**

(a) Design new process/system/policies

(b) Determine effect of different priorities

(c) Forecast production levels/required resources

(d) Estimate cost of alternatives

* **Management Control**

(a) Improve throughput

(b) Identify effect of changes in resource capacities/equipment failures.

(c) Identify effect of delays in raw materials

(d) Improve system efficiency

* **Operational Control**

(a) Optimize equipment or machine utilization

(b) Significantly reduce bottlenecks

(c) Define operational requirements

(d) Identify critical operation rates

(e) Optimize staffing configurations

(f) Reduce in-process inventories

(g) Reduce processing time

(h) Optimize buffer capacities

6.5 Simulation and shop floor planning

The manufacturing planning function determines the facilities and processes required to produce the appropriate volume and quality of product. As such, it includes the selection and sizing of the components of the manufacturing environments; machines such as lathes and mills, material handling equipment such as forklifts and AGVs, and storage facilities such as ASRS and racks.

Equipment reliabilities and facility layouts are also an integral part of the manufacturing planning activity. Simulation currently plays a critical role for many shop floor planning functions. A model of the proposed production process is created and used to predict shop floor performance (part flow time, machine utilization, pinch points, inventory levels, queue lengths, etc.). The planner evaluates these parameters and then adds capabilities to alleviate bottlenecks and reduces other capabilities to save costs. In this manner, the most cost effective plan which achieves and desired throughput level can be discovered and implemented.

Once the above process is completed, the simulation model can then be used to evaluate the sensitivity of the plan relative to uncertain machine performance data and questionable reliability projections. The planner thus performs a risk analysis to determine the likelihood that the plan will really achieve the desired results (or to determine how much extra it will cost to ensure that the desired goals will be attained even in the worst case scenarios.) Similarly, the model can also be employed to assess the system's flexibility (its performance as a function of product mix.)

6.6 Simulation and shop floor control

Manufacturing control involves releasing the workload to the shop floor at specified times, causing materials to be available when necessary, scheduling equipment and operators, and specifying routing, priorities, and other flow characteristics. In essence, once orders for specified products are available, manufacturing control determines how to process the materials through the available facilities. Examples of current capabilities available to assist in the shop floor control process are Material Requirements Planning (MRP) packages, part routing data bases ,Gantt Charts, scheduling tools, and simulation. All of these tools offer assistance to the control process in different ways. Simulation provides benefits in two areas; setting control procedures and supporting on-line control.

To set control procedures for the manufacturing process simulation is used in a manner similar to its use in manufacturing planning. A model of the manufacturing process is constructed and executed with a given product demand. This first model is configured and executed with those operating procedures that are currently employed (for existing systems) or are proposed by future system operators (for planned systems). These procedures include routing decision logic, AGV deadlock breaking rules, machine queue priorities, lot sizing parameters, preventive maintenance schedules, etc. Proposed improvements in these general rules are then installed in the model and tested for effectiveness. Alternative procedures are designed and tested until a set of operating rules is discovered that achieves the performance objectives. These acceptable rules then become control guidelines for the operators of the actual system.

6.7 A Case Study

Case studies have provided the momentum that has resulted in most of the major industrial developments throughout history. This study presents a methodology for effective use of simulation on shop floor and describes how a particular decision will impact the shop floor environment.

6.7.1 Objectives

The objectives of the study are:

1) To study how technology can be used to control shop floor activities in an integrated manufacturing system. Use of simulation as an analysis tool, allows manufacturing engineers to better control the interaction between shop floor activities.

2) To develop a simulation model of a job-shop type shop floor, and to evaluate the following performance measures of the system:

1. Machine utilization
2. Average flow time
3. Queue length

3) To analyze the effects of different job arrival rates on performance measures when it follows,

1. Normal Distribution
2. Exponential Distribution
3. Uniform Distribution

6.7.2 Model Definition

The system required to simulate is a job shop type shop floor. The shop floor consists of fifteen number of machines, which can perform eight different operations. Machines can be divided into two major categories, automated and partially automated. Automated machines are able to perform two to three of the eight possible operations and the partially automated machines can only perform one operation. Each operation implies a unique class of machining activity, such as drilling, milling and grinding, etc.

6.7.3 Problem Statement

Jobs arrive to the shop floor according to a known distribution with a mean interval time of 9.6 minutes. The job mix consists of six jobs types, with each type having a different machine visitation sequence with known precedence order. Figure 6.2 shows the detailed job data. Each product requires different operation times on each machine as shown in Figure 6.3. All operation times are distributed according to a known distribution.

6.7.4 Assumptions

1- No budget or plant space restrictions are considered. Over times are also disregarded.

2- Set up times are included in the total job flow time in the system.

3- Each operation of a given job type will be assigned to only one machine type for the entire demand, or each machine can only perform the only operation it was assigned for, even if it cannot be fully utilized.

4- Probability of arriving different jobs are equal.

6.7.5 Methodology

6.7.5.1 Random Number Generation

SIMAN Simulation language is used in order to get

Job Type	Mean Daily Demand	Standard Deviation	Lot Size	Operation Precedence Requirements
A	140	12	20	#2, #7, #5, #2
B	60	8	10	#5, #4, #6, #8
C	80	18	8	#3, #6, #2
D	165	30	13	#1, #2, #3
E	52	15	5	#1, #3, #6, #8, #2
F	110	14	11	#6, #4, #8, #2

Fig. 6.2 Job Data

Machine Name	Machine Category	Operations Capability	Unit Operation Time (min.)
M01	Automated	#1	1.70
		#2	1.20
M02		#1	1.90
		#4	2.40
		#5	0.90
M03		#6	1.25
		#8	2.40
M04		#3	1.25
		#4	2.05
M05		#4	3.10
		#5	1.10
		#6	2.90
M06		#2	2.85
		#3	2.25
		#7	3.15
M07		#2	1.50
		#8	3.35
M08	Partially Automated	#1	4.10
M09		#2	3.60
M10		#3	2.70
M11		#4	5.20
M12		#5	1.50
M13		#6	4.70
M14		#7	5.20
M15		#8	4.50

Fig 6.3 Machine Data

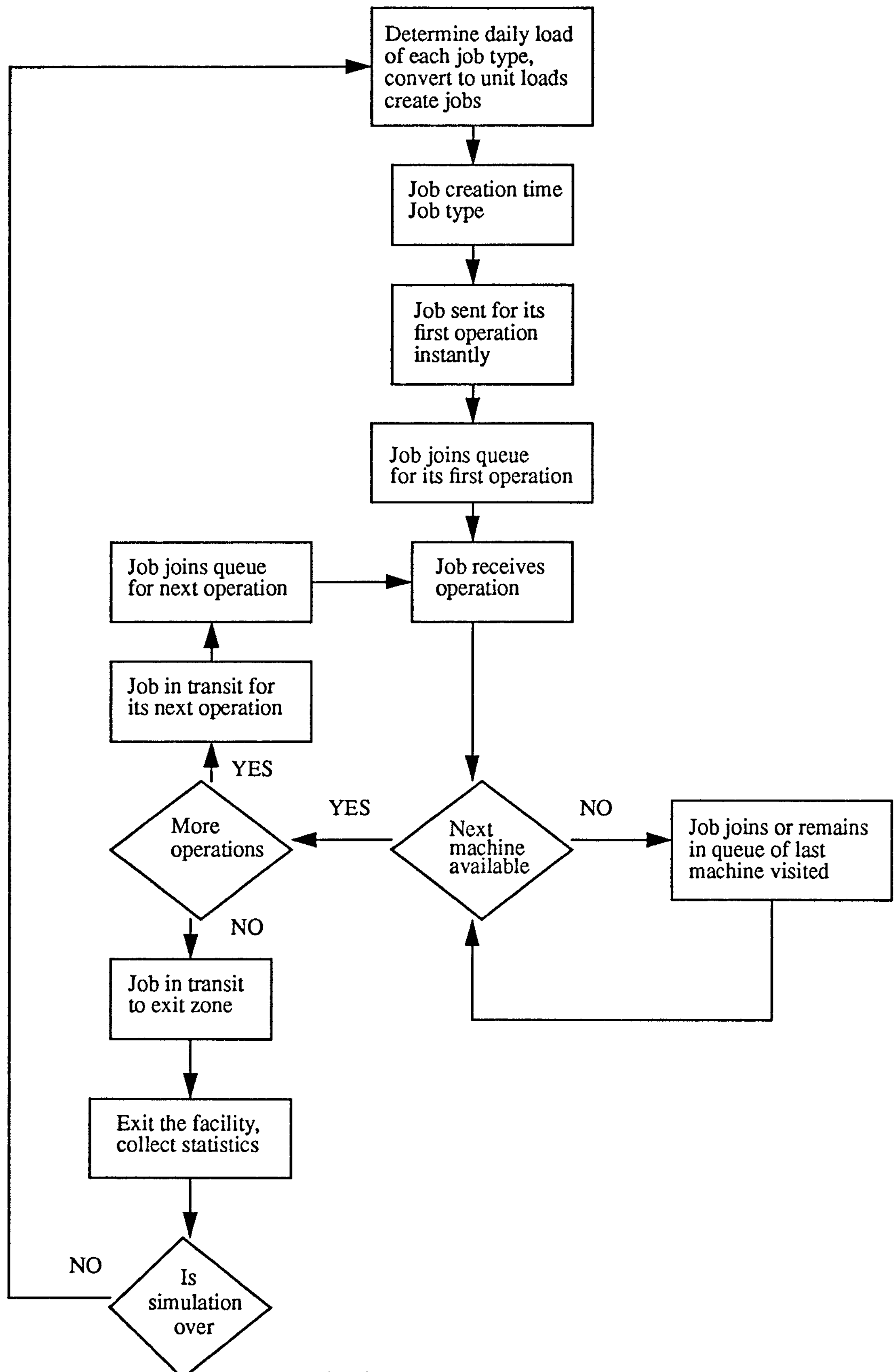


Fig 6.4 Flow Chart of SIMAN Simulation Model

performance measures i.e. job flow times, machine queue lengths and machine utilization factors. As outlined in the flow chart of SIMAN simulation model (Figure 6.4), number of jobs of each type are created at random using the corresponding distribution parameters and then converted into unit loads with the help of random number generations. Using Job type D to illustrate, a random number is drawn each day from N(165,30) divided by 13 and rounded down to get the number unit loads of job type D. If the random number drawn is 145, there will be

(145/13) = 11, unit loads of job type D.

Each unit load , job D requires,

13 X 3.60 = 46.8 minutes

on machine, M09, if the partially automated machine M09 has been chosen for operation number 2 needed by job D. Similar results for each operation, performed on different machines are tabulated in Figure 6.5.

To reflect the affect of random operation times, total operation time of each unit load is allowed to have a standard deviation which is equal to 20% of the mean found above. SIMAN's experiment frame would include among others, a parameter of N(46.8, 9.36) for above job operation machine combination.

6.7.5.2 Model Building

Simulation models have been developed to study and analyze the parameters at different arrival rates. The performance

Machine Name	Operating Capability	Operations Required For Jobs:																							
		A				B				C			D				E					F			
		2	7	5	2	5	4	6	8	3	6	2	1	2	3	6	1	3	6	8	2	6	4	8	2
M01	#1												22				9								
	#2	24			24							10		16							6				13
M02	#1												25				10								
	#4						24																26		
	#5			18		9																			
M03	#6							13			10					16			6			14			
	#8								24															26	
M04	#3									10					16			6							
	#4						21																23		
M05	#4						31																34		
	#5			22		11																			
	#6							29			23					38			15			32			31
M06	#2	57			57							23		37							14				
	#3									18					29			11							
	#7																								
M07	#2	30			30							12		20							8				17

Fig. 6.5 Processing Time Chart

Machine Name	Operating Capability	Operations Required For Jobs:																							
		A				B				C			D				E					F			
		2	7	5	2	5	4	6	8	3	6	2	1	2	3	6	1	3	6	8	2	6	4	8	2
	#8								34											17				37	
M08	#1												53				21								
M09	#2	72			72							29		47							18				40
M10	#3									22					35			14							
M11	#4						52																57		
M12	#5			30		15																			
M13	#6							47			38					61			24			52			
M14	#7		104																						
M15	#8								45											23				50	

Fig. 6.5 (con't) Processing Time Chart

measures are the Weighted Average Job Flow Times (WAJFT) in minutes, Average Queue Length (AQL) in number of jobs, and the Average Machine Utilization (AMU) as percentage. Figures 6.6, 6.7 and 6.8 show the SIMAN's simulation models for each distribution.

6.7.5.3 Experimental Design

Different alternatives has been simulated using Experimental designs to determine the length of the initialization period. The length of simulation runs and the number of replications to make of each run. Figures 6.9, 6.10 and 6.11 show the experimental designs for each case.

6.7.5.4 Simulation Runs

Simulation runs were conducted for each case to evaluate performance measures and their subsequent analysis. SIMAN Summary Reports are shown in Figure 6.12, Figure 6.13 and 6.14.

6.8 Results and Analysis

The models described in previous sections was simulated and the results and their analysis are presented in Figure 6.15. From Figures 6.12, 6.13, 6.14, 6.15, the following inferences can be made:

1. Average Machine Utilization (AMU) is 58% , if arrival rate follows Exponential Distribution.

```
BEGIN;
             CREATE:RN(2,1):MARK(3);
             ASSIGN:A(2)=DP(1,1);
JOBS              ASSIGN:NS=A(2);
             ROUTE:0.0,SEQ;
             STATION,1-8;
             QUEUE,M;
             SEIZE:MACHINE(M);
             DELAY:A(1);
             RELEASE:MACHINE(M):
                       NEXT(JOBS);

             STATION,9;
             TALLY:A(2),INT(2);
             TALLY:7,INT(2):DISPOSE;
END;
```

Fig 6.6   Model 1

```
BEGIN;
                CREATE:EX(2,1):MARK(3);
                ASSIGN:A(2)=DP(1,1);
                ASSIGN:NS=A(2);
JOBS            ROUTE:0.0,SEQ;
                STATION,1-8;
                QUEUE,M;
                SEIZE:MACHINE(M);
                DELAY:A(1);
                RELEASE:MACHINE(M):
                          NEXT(JOBS);
                STATION,9;
                TALLY:A(2),INT(2);
                TALLY:7,INT(2):DISPOSE;
END;
```

Fig 6.7 Model 2

```
BEGIN;
                CREATE:UN(2,1):MARK(3);
                ASSIGN:A(2)=DP(1,1);
                ASSIGN:NS=A(2);
JOBS            ROUTE:0.0,SEQ;
                STATION,1-8;
                QUEUE,M;
                SEIZE:MACHINE(M);
                DELAY:A(1);
                RELEASE:MACHINE(M):
                          NEXT(JOBS);
                STATION,9;
                TALLY:A(2),INT(2);
                TALLY:7,INT(2):DISPOSE;
END;
```

Fig 6.8 Model 3

```
BEGIN;
PROJECT,JOB SHOP,TAHIR,4/10/92;
DISCRETE,75,6,8,9;
RESOURCES:1-8,MACHINE,2,2,1,2,2,2,2,2;
;
SEQUENCES:
          1,2,RN(3,1) & 7,RN(4,1) & 5,RN(5,1) & 2,RN(3,1) & 9:
          2,5,RN(6,1) & 4,RN(7,1) & 6,RN(8,1) & 8,RN(9,1) & 9:
          3,3,RN(10,1) & 6,RN(11,1) & 2,RN(12,1) & 9:
          4,1,RN(13,1) & 2,RN(14,1) & 3,RN(15,1) & 6,RN(16,1) & 9:
          5,1,RN(17,1)& 3,RN(18,1)&6,RN(19,1)&8,RN(20,1)&2,RN(21,1)&9:
          6,6,RN(22,1)&4,RN(23,1)&8,RN(24,1)&2,RN(25,1)&9;
;
PARAMETERS: 1,.166,1,.332,2,.498,3,.664,4,.83,5,1.0,6:
            2,9.6,.4:
            3,24,.5 : 4,63,.4 : 5,22,.3:
            6,11,.2 : 7,21,.3 : 8,13,.1 : 9,34,.4:
            10,22,.3 : 11,10,.1 : 12,10,.2:
            13,25,.4 : 14,16,.2 : 15,35,.4 : 16,16,.2:
            17,10,.2 : 18,14,.2 : 19,6,.1 : 20,17,.3 : 21,6,.1:
            22,14,.2 : 23,23,.4 : 24,37,.4 : 25,13,.3;
;
DSTAT:1,NQ(1),MACHINE 1 QUEUE:
      2,NQ(2),MACHINE 2 QUEUE:
      3,NQ(3),MACHINE 3 QUEUE:
      4,NQ(4),MACHINE 4 QUEUE:
      5,NQ(5),MACHINE 5 QUEUE:
      6,NQ(6),MACHINE 6 QUEUE:
      7,NQ(7),MACHINE 7 QUEUE:
      8,NQ(8),MACHINE 8 QUEUE:
      9,NR(1),MACHINE 1 UTIL:
      10,NR(2),MACHINE 2 UTIL:
      11,NR(3),MACHINE 3 UTIL:
      12,NR(4),MACHINE 4 UTIL:
      13,NR(5),MACHINE 5 UTIL:
      14,NR(6),MACHINE 6 UTIL:
      15,NR(7),MACHINE 7 UTIL:
      16,NR(8),MACHINE 8 UTIL;
;
TALLIES : 1,TIME JOB 1:
          2,TIME JOB 2:
          3,TIME JOB 3:
          4,TIME JOB 4:
          5,TIME JOB 5:
          6,TIME JOB 6:
          7,OVERALL FLOWTIME;
REPLICATE,1,0,960;
;
TRACE,,,A(1);
;
END;
```

Fig 6.9 Experiment Frame 1

```
BEGIN;
PROJECT,JOB SHOP,TAHIR,4/12/92;
DISCRETE,75,6,8,9;
RESOURCES:1-8,MACHINE,2,2,1,2,2,2,2,2;
;
SEQUENCES:
          1,2,EX(3,1)&7,EX(4,1)&5,EX(5,1)&2,EX(3,1)&9:
          2,5,EX(6,1)&4,EX(7,1)&6,EX(8,1)&8,EX(9,1)&9:
          3,3,EX(10,1)&6,EX(11,1)&2,EX(12,1)&9:
          4,1,EX(13,1)&2,EX(14,1)&3,EX(15,1)&6,EX(16,1)&9:
          5,1,EX(17,1)&3,EX(18,1)&6,EX(19,1)&8,EX(20,1)&9:
          6,6,EX(22,1)&4,EX(23,1)&8,EX(24,1)&2,EX(25,1)&9;
;
PARAMETERS: 1,.166,1,.332,2,.498,3,.664,4,.83,5,1.0,6:
            2,9.6:
            3,24 : 4,63 : 5,22:
            6,11  : 7,21 : 8,13 : 9,34:
            10,22 : 11,10 : 12,10:
            13,25 : 14,16 : 15,35 : 16,16:
            17,10 : 18,14 : 19,6  : 20,17 : 21,6:
            22,14 : 23,23 : 24,37 : 25,13;
;
DSTAT:1,NQ(1),MACHINE 1 QUEUE:
      2,NQ(2),MACHINE 2 QUEUE:
      3,NQ(3),MACHINE 3 QUEUE:
      4,NQ(4),MACHINE 4 QUEUE:
      5,NQ(5),MACHINE 5 QUEUE:
      6,NQ(6),MACHINE 6 QUEUE:
      7,NQ(7),MACHINE 7 QUEUE:
      8,NQ(8),MACHINE 8 QUEUE:
      9,NR(1),MACHINE  1 UTIL:
      10,NR(2),MACHINE 2 UTIL:
      11,NR(3),MACHINE 3 UTIL:
      12,NR(4),MACHINE 4 UTIL:
      13,NR(5),MACHINE 5 UTIL:
      14,NR(6),MACHINE 6 UTIL:
      15,NR(7),MACHINE 7 UTIL:
      16,NR(8),MACHINE 8 UTIL;
;
TALLIES : 1,TIME  JOB 1:
          2,TIME  JOB 2:
          3,TIME  JOB 3:
          4,TIME  JOB 4:
          5,TIME  JOB 5:
          6,TIME  JOB 6:
          7,OVERALL FLOWTIME;
REPLICATE,1,0,960;
;
TRACE,,,A(1);
;
END;
```

Fig 6.10 Experiment Frame 2

```
BEGIN;
PROJECT,JOB SHOP,TAHIR,4/12/92;
DISCRETE,75,6,8,9;
RESOURCES:1-8,MACHINE,2,2,1,2,2,2,2,2;
;
SEQUENCES:
          1,2,UN(3,1)&7,UN(4,1)&5,UN(5,1)&2,UN(3,1)&9:
          2,5,UN(6,1)&4,UN(7,1)&6,UN(8,1)&8,UN(9,1)&9:
          3,3,UN(10,1)&6,UN(11,1)&2,UN(12,1)&9:
          4,1,UN(13,1)&2,UN(14,1)&3,UN(15,1)&6,UN(16,1)&9:
          5,1,UN(17,1)&3,UN(18,1)&6,UN(19,1)&8,UN(20,1)&9:
          6,6,UN(22,1)&4,UN(23,1)&8,UN(24,1)&2,UN(25,1)&9;
;
PARAMETERS: 1,.166,1,.332,2,.498,3,.664,4,.83,5,1.0,6:
            2,9.6,.4:
            3,24,.5 : 4,63,.4 : 5,22,.3:
            6,11,.2 : 7,21,.3 : 8,13,.1 : 9,34,.4:
            10,22,.3 : 11,10,.1 : 12,10,.2:
            13,25,.4 : 14,16,.2 : 15,35,.4 : 16,16,.2:
            17,10,.2 : 18,14,.2 : 19,6,.1  : 20,17,.3 : 21,6,.1:
            22,14,.2 : 23,23,.4 : 24,37,.4 : 25,13,.3;
;
DSTAT:1,NQ(1),MACHINE 1 QUEUE:
      2,NQ(2),MACHINE 2 QUEUE:
      3,NQ(3),MACHINE 3 QUEUE:
      4,NQ(4),MACHINE 4 QUEUE:
      5,NQ(5),MACHINE 5 QUEUE:
      6,NQ(6),MACHINE 6 QUEUE:
      7,NQ(7),MACHINE 7 QUEUE:
      8,NQ(8),MACHINE 8 QUEUE:
      9,NR(1),MACHINE  1 UTIL:
      10,NR(2),MACHINE 2 UTIL:
      11,NR(3),MACHINE 3 UTIL:
      12,NR(4),MACHINE 4 UTIL:
      13,NR(5),MACHINE 5 UTIL:
      14,NR(6),MACHINE 6 UTIL:
      15,NR(7),MACHINE 7 UTIL:
      16,NR(8),MACHINE 8 UTIL;
;
TALLIES : 1,TIME  JOB 1:
          2,TIME  JOB 2:
          3,TIME  JOB 3:
          4,TIME  JOB 4:
          5,TIME  JOB 5:
          6,TIME  JOB 6:
          7,OVERALL FLOWTIME;
REPLICATE,1,0,960;
;
TRACE,,,A(1);
;
END;
```

Fig 6.11 Experiment Frame 3

SIMAN IV - License #8810506
New Jersey Institute of Tech.

Summary for Replication 1 of 1

Project: JOB SHOP — Run execution date : 5/ 4/1992
Analyst: TAHIR — Model revision date: 4/10/1992

Replication ended at time : 960.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
TIME JOB 1	454.30	.45587	170.06	926.55	14
TIME JOB 2	432.93	.63569	75.396	899.77	16
TIME JOB 3	620.68	.32262	275.77	886.95	9
TIME JOB 4	481.94	.53074	96.782	931.80	14
TIME JOB 5	530.08	.54076	124.72	919.77	12
TIME JOB 6	545.65	.50568	201.81	931.67	9
OVERALL FLOWTIME	498.54	.50593	75.396	931.80	74

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
MACHINE 1 QUEUE	.01303	8.7047	.00000	1.0000	.00000
MACHINE 2 QUEUE	.60069	1.7777	.00000	5.0000	.00000
MACHINE 3 QUEUE	6.8978	.87537	.00000	17.000	15.000
MACHINE 4 QUEUE	.00674	12.137	.00000	1.0000	.00000
MACHINE 5 QUEUE	.00146	26.145	.00000	1.0000	.00000
MACHINE 6 QUEUE	.06925	4.7122	.00000	3.0000	.00000
MACHINE 7 QUEUE	.06077	3.9313	.00000	1.0000	.00000
MACHINE 8 QUEUE	.09359	3.2349	.00000	2.0000	2.0000
MACHINE 1 UTIL	.73371	.88321	.00000	2.0000	.00000
MACHINE 2 UTIL	1.4198	.52781	.00000	2.0000	2.0000
MACHINE 3 UTIL	.93315	.26765	.00000	1.0000	1.0000
MACHINE 4 UTIL	.64709	1.0023	.00000	2.0000	1.0000
MACHINE 5 UTIL	.57570	1.0942	.00000	2.0000	1.0000
MACHINE 6 UTIL	.81754	.88981	.00000	2.0000	2.0000
MACHINE 7 UTIL	1.0487	.74981	.00000	2.0000	.00000
MACHINE 8 UTIL	1.1653	.68072	.00000	2.0000	2.0000

Run Time: 0 min(s) 50 sec(s)
Simulation run complete.

Fig 6.12 SIMAN Output Report

SIMAN IV - License #8810506
New Jersey Institute of Tech.

Summary for Replication 1 of 1

Project: JOB SHOP — Run execution date : 5/ 4/1992
Analyst: TAHIR — Model revision date: 4/12/1992

Replication ended at time : 960.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
TIME JOB 1	559.00	.38877	176.71	899.77	17
TIME JOB 2	515.45	.57131	66.517	937.89	22
TIME JOB 3	488.07	.49582	140.00	924.70	20
TIME JOB 4	545.15	.50218	187.71	949.41	9
TIME JOB 5	679.99	.34323	322.17	951.00	11
TIME JOB 6	522.27	.40839	209.65	903.24	12
OVERALL FLOWTIME	541.29	.46193	66.517	951.00	91

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
MACHINE 1 QUEUE	.28377	2.6969	.00000	5.0000	.00000
MACHINE 2 QUEUE	2.8889	.90919	.00000	8.0000	1.0000
MACHINE 3 QUEUE	10.892	.77429	.00000	26.000	25.000
MACHINE 4 QUEUE	.07292	3.7882	.00000	2.0000	.00000
MACHINE 5 QUEUE	.11826	3.4762	.00000	2.0000	.00000
MACHINE 6 QUEUE	.13791	3.1296	.00000	3.0000	.00000
MACHINE 7 QUEUE	.18304	2.1713	.00000	2.0000	.00000
MACHINE 8 QUEUE	.46966	2.1480	.00000	5.0000	.00000
MACHINE 1 UTIL	.86682	.91226	.00000	2.0000	1.0000
MACHINE 2 UTIL	1.6813	.37906	.00000	2.0000	2.0000
MACHINE 3 UTIL	.93101	.27222	.00000	1.0000	1.0000
MACHINE 4 UTIL	.91961	.84862	.00000	2.0000	.00000
MACHINE 5 UTIL	.74153	1.0643	.00000	2.0000	1.0000
MACHINE 6 UTIL	.94822	.81140	.00000	2.0000	1.0000
MACHINE 7 UTIL	.90331	.88949	.00000	2.0000	1.0000
MACHINE 8 UTIL	1.3713	.51248	.00000	2.0000	.00000

Run Time: 0 min(s) 52 sec(s)
Simulation run complete.

Fig 6.13 SIMAN Output Report

SIMAN IV - License #9010703
New Jersey Institute of Tech.

Summary for Replication 1 of 1

Project: JOB SHOP   Run execution date : 5/ 5/1992
Analyst: TAHIR   Model revision date: 4/12/1992

Replication ended at time : 960.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
TIME JOB 1	512.14	.55221	84.852	936.77	24
TIME JOB 2	523.11	.54947	55.385	922.30	34
TIME JOB 3	537.37	.49729	54.679	938.52	29
TIME JOB 4	500.04	.51604	101.27	940.86	23
TIME JOB 5	513.16	.50129	99.004	949.74	34
TIME JOB 6	594.02	.43079	100.06	950.89	26
OVERALL FLOWTIME	529.73	.50301	54.679	950.89	170

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
MACHINE 1 QUEUE	.00731	11.654	.00000	1.0000	.00000
MACHINE 2 QUEUE	.40633	2.2927	.00000	6.0000	.00000
MACHINE 3 QUEUE	7.5352	.43255	.00000	13.000	11.000
MACHINE 4 QUEUE	.05285	4.6519	.00000	2.0000	.00000
MACHINE 5 QUEUE	.02041	6.9279	.00000	1.0000	.00000
MACHINE 6 QUEUE	.15307	3.5456	.00000	4.0000	.00000
MACHINE 7 QUEUE	.06656	3.8969	.00000	2.0000	.00000
MACHINE 8 QUEUE	.76240	1.5226	.00000	5.0000	.00000
MACHINE 1 UTIL	.63253	1.0656	.00000	2.0000	.00000
MACHINE 2 UTIL	1.2466	.62791	.00000	2.0000	.00000
MACHINE 3 UTIL	.95349	.22085	.00000	1.0000	1.0000
MACHINE 4 UTIL	.69081	1.1020	.00000	2.0000	1.0000
MACHINE 5 UTIL	.46098	1.4351	.00000	2.0000	1.0000
MACHINE 6 UTIL	.90851	.87148	.00000	2.0000	1.0000
MACHINE 7 UTIL	.88995	.92619	.00000	2.0000	2.0000
MACHINE 8 UTIL	1.4239	.53191	.00000	2.0000	2.0000

Run Time: 1 min(s) 30 sec(s)
Simulation run complete.

Fig 6.14 SIMAN Output Report

Parameters / Distributions	Weighted Average Job Flow Time (WAJFT) min.	Average Queue Length (AQL) no. of jobs	Average Machine Utilization (AMU) %
Normal	498	0.97	52
Exponential	541	1.88	58
Uniform	529	1.13	51

Fig 6.15 Comparisons of the Results

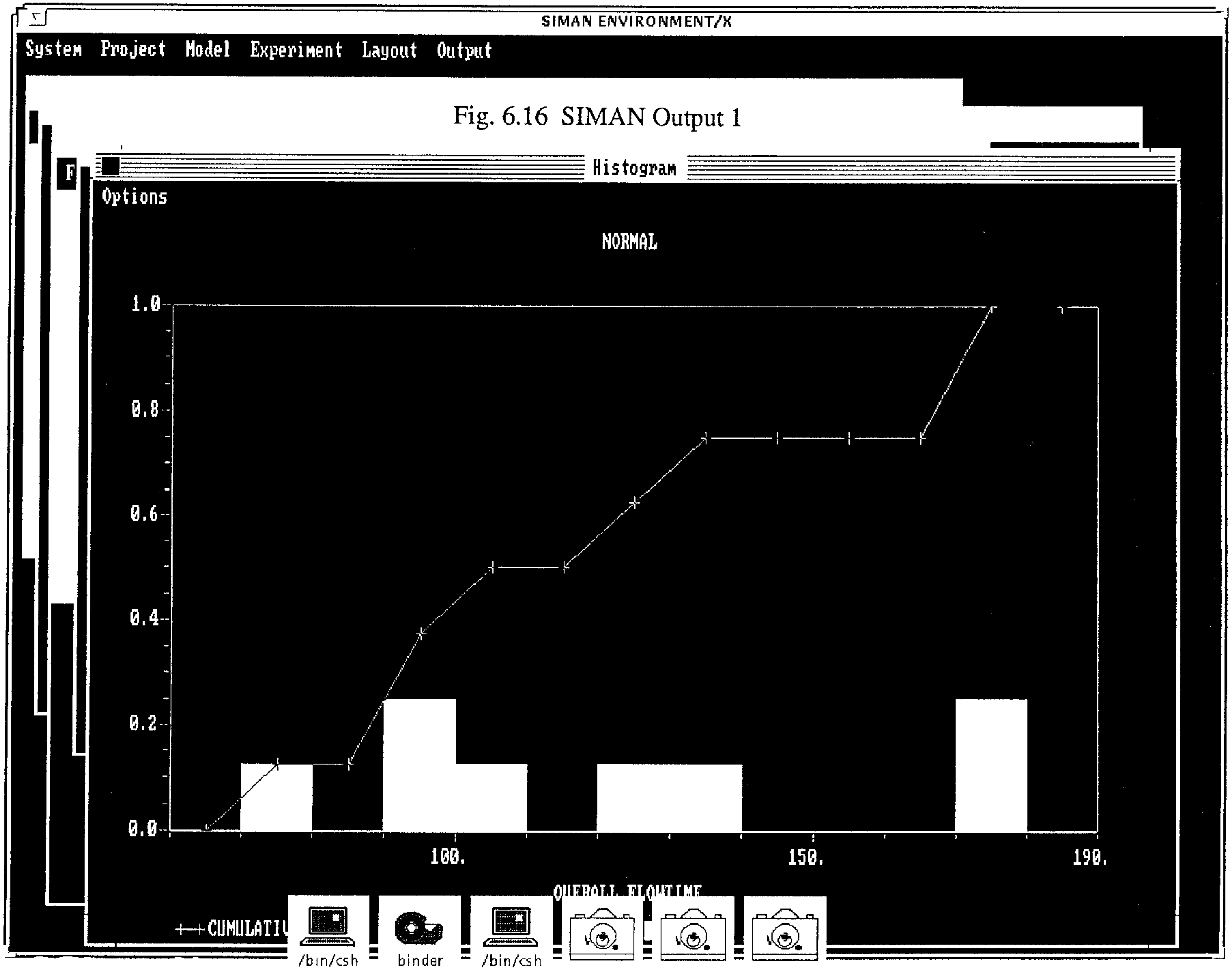


Fig. 6.16 SIMAN Output 1

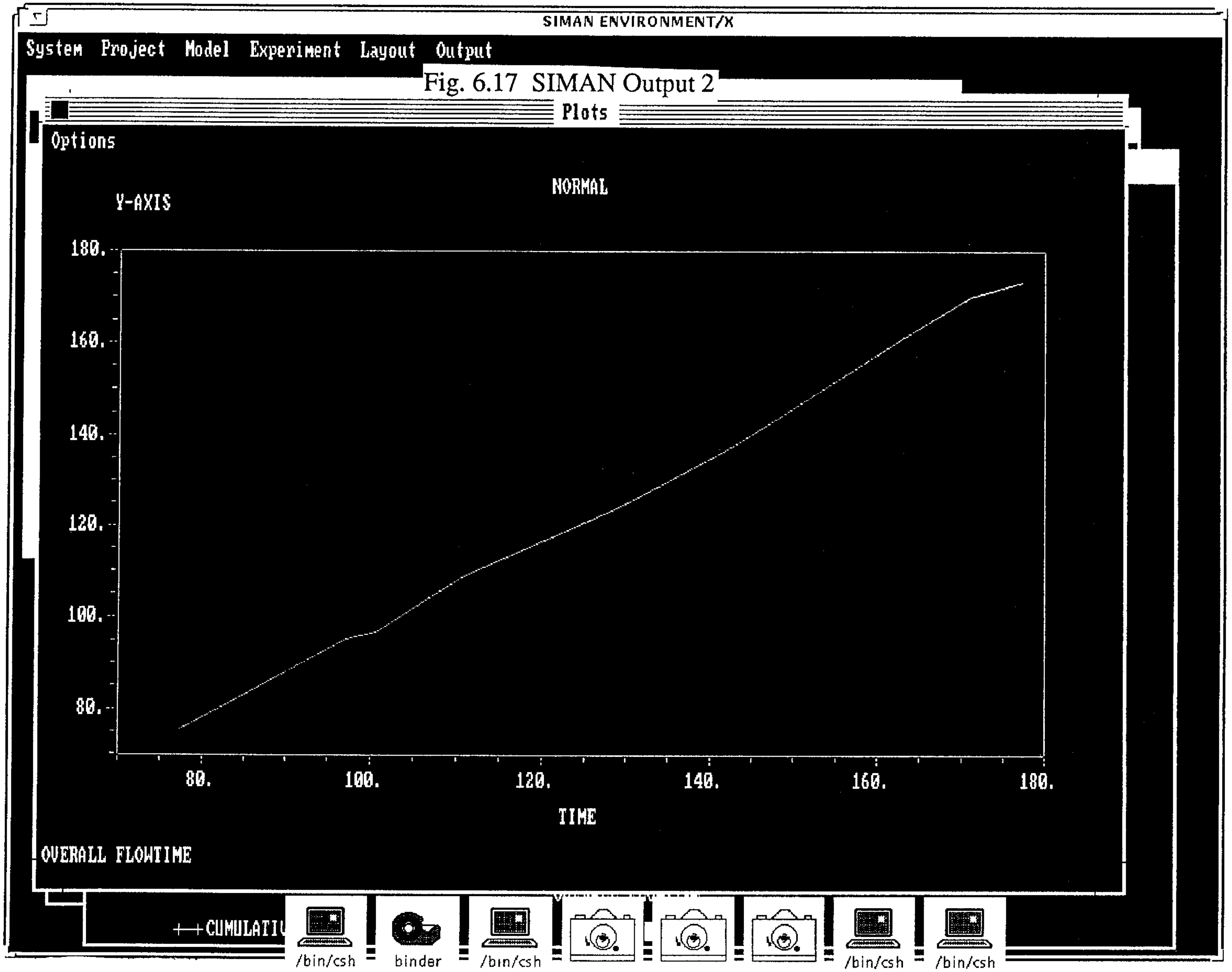


Fig. 6.17 SIMAN Output 2

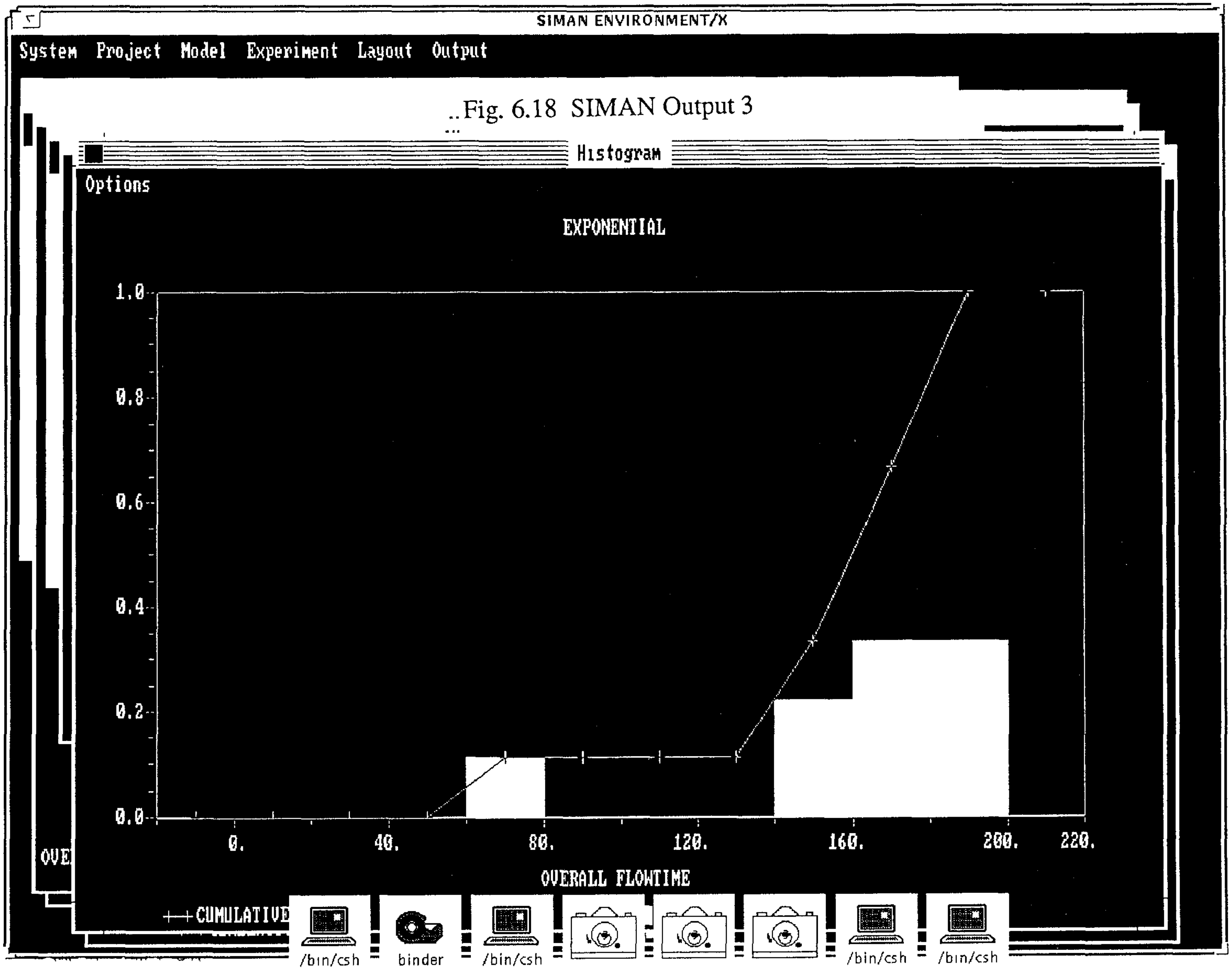
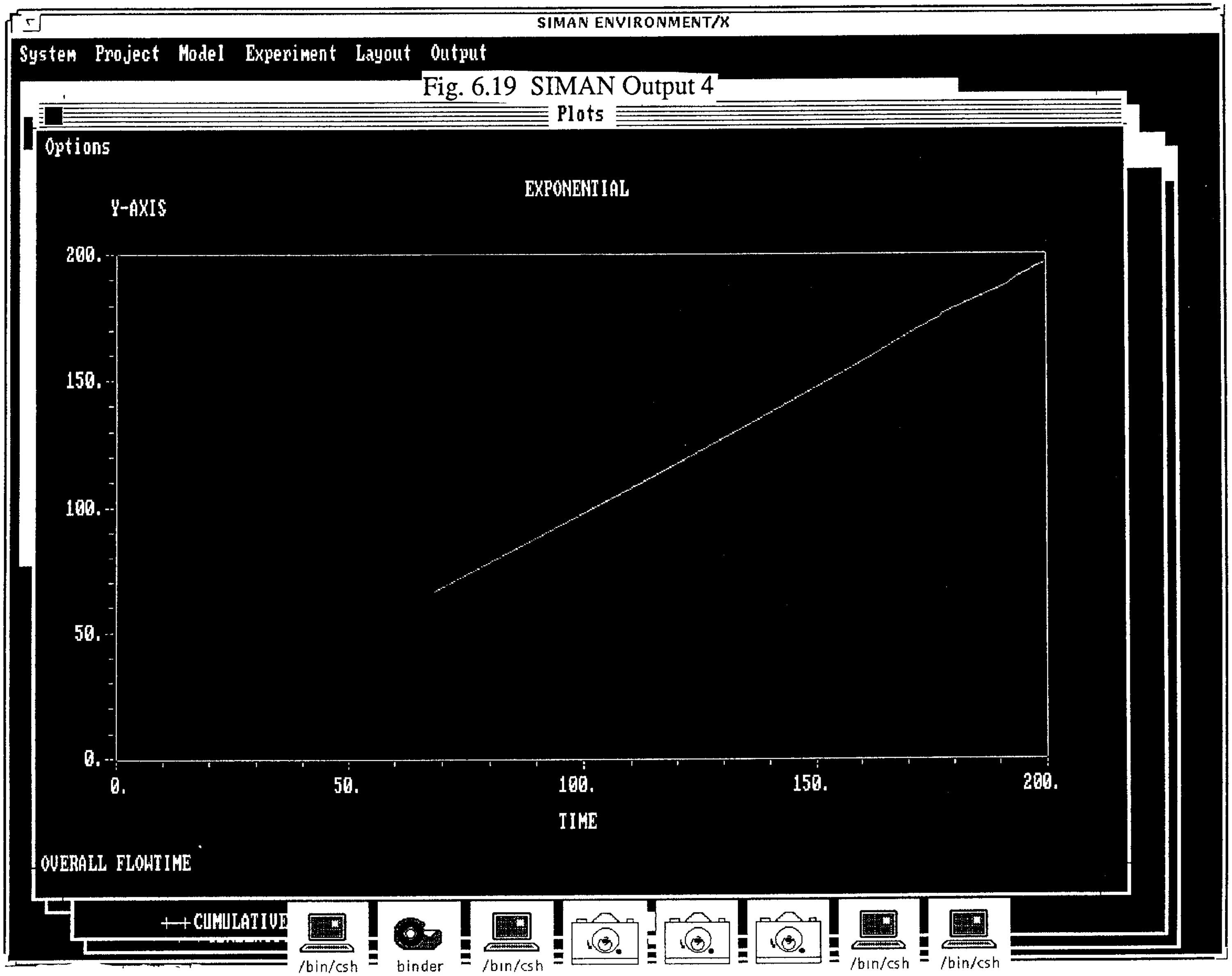


Fig. 6.18 SIMAN Output 3

Fig. 6.19 SIMAN Output 4



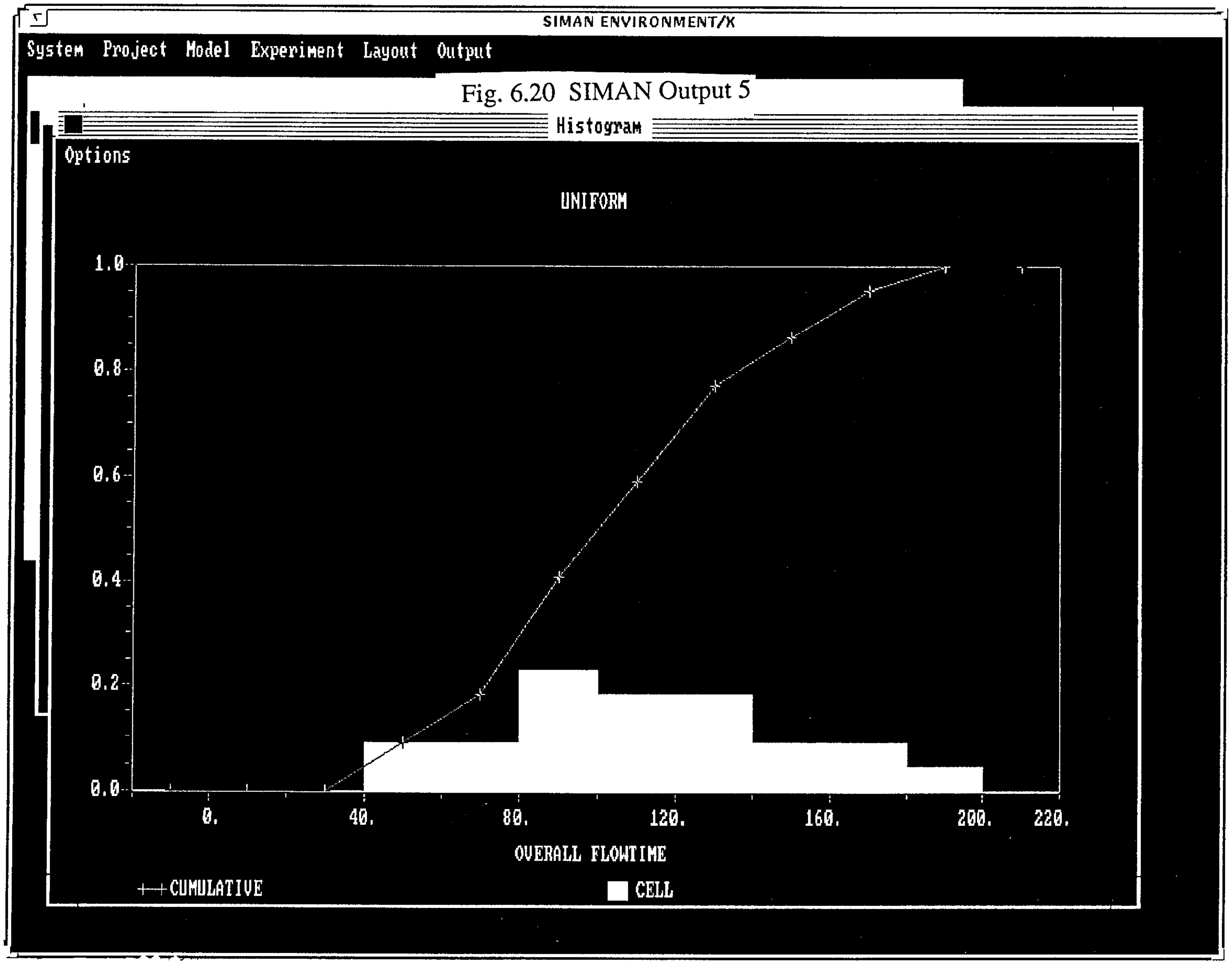


Fig. 6.20 SIMAN Output 5

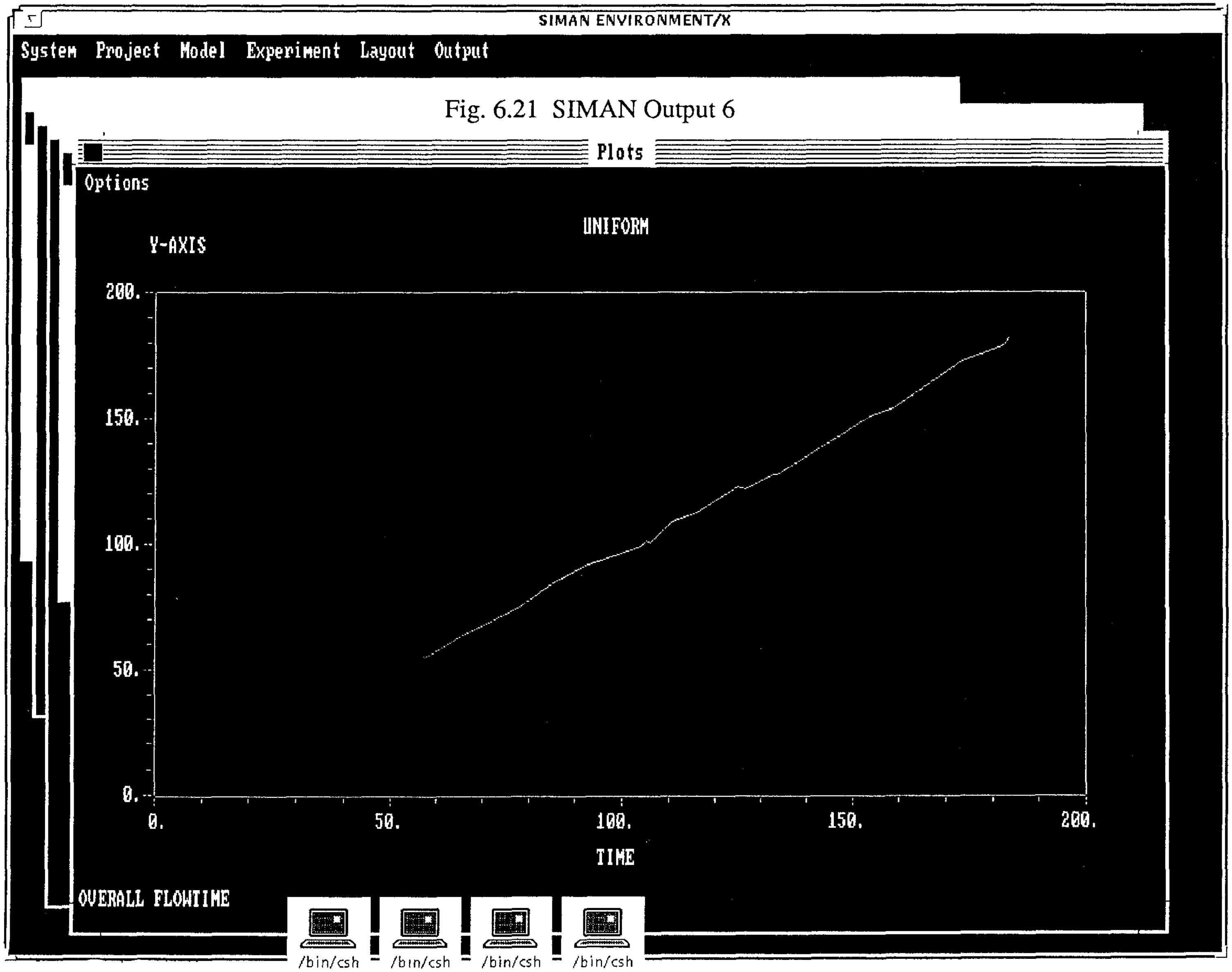


Fig. 6.21 SIMAN Output 6

Blank Page

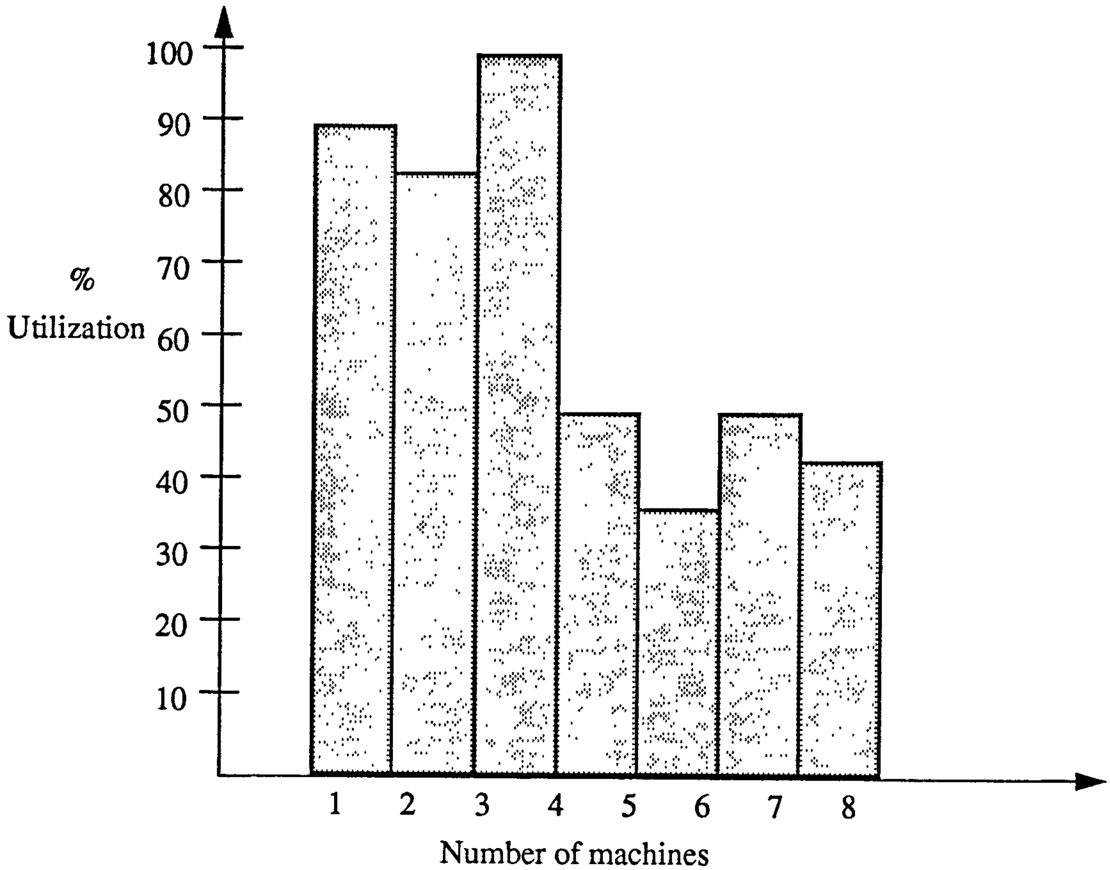


Fig 6.23 Exponential Distribution

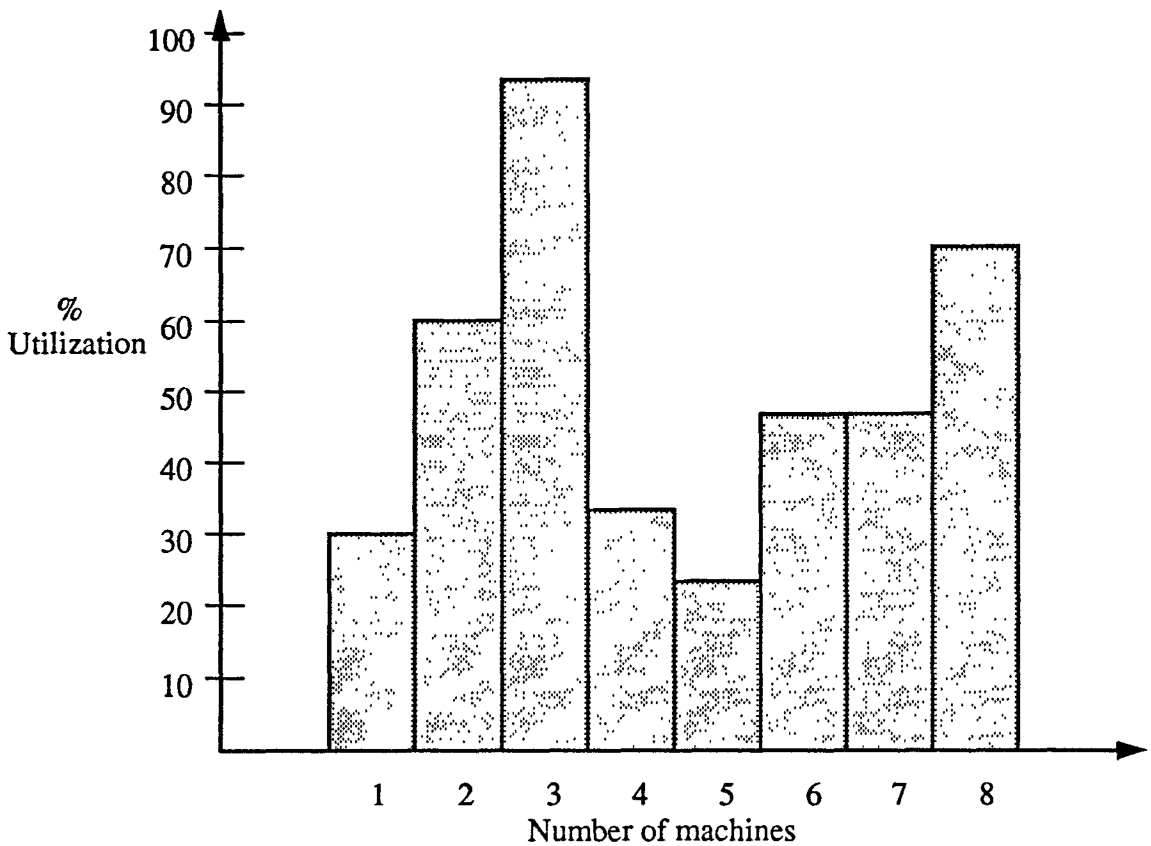


Fig 6.24 UniformDistribution

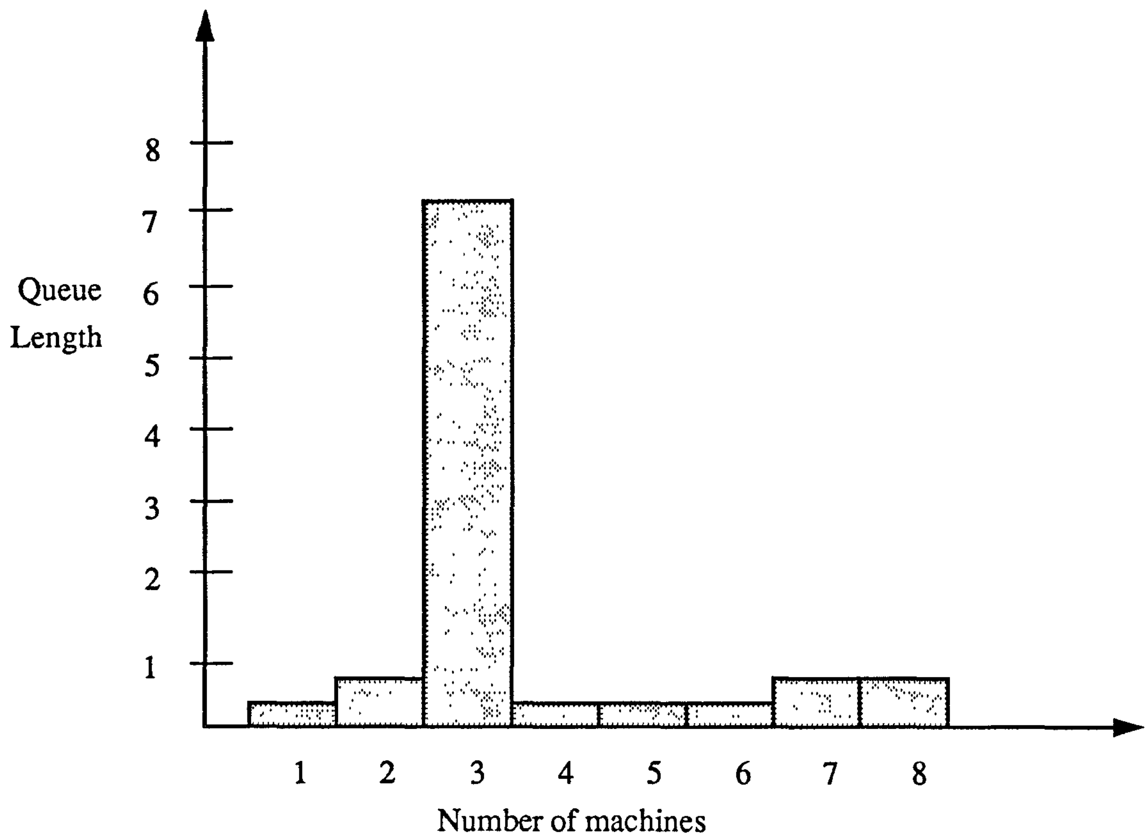


Fig 6.25 Normal Distribution

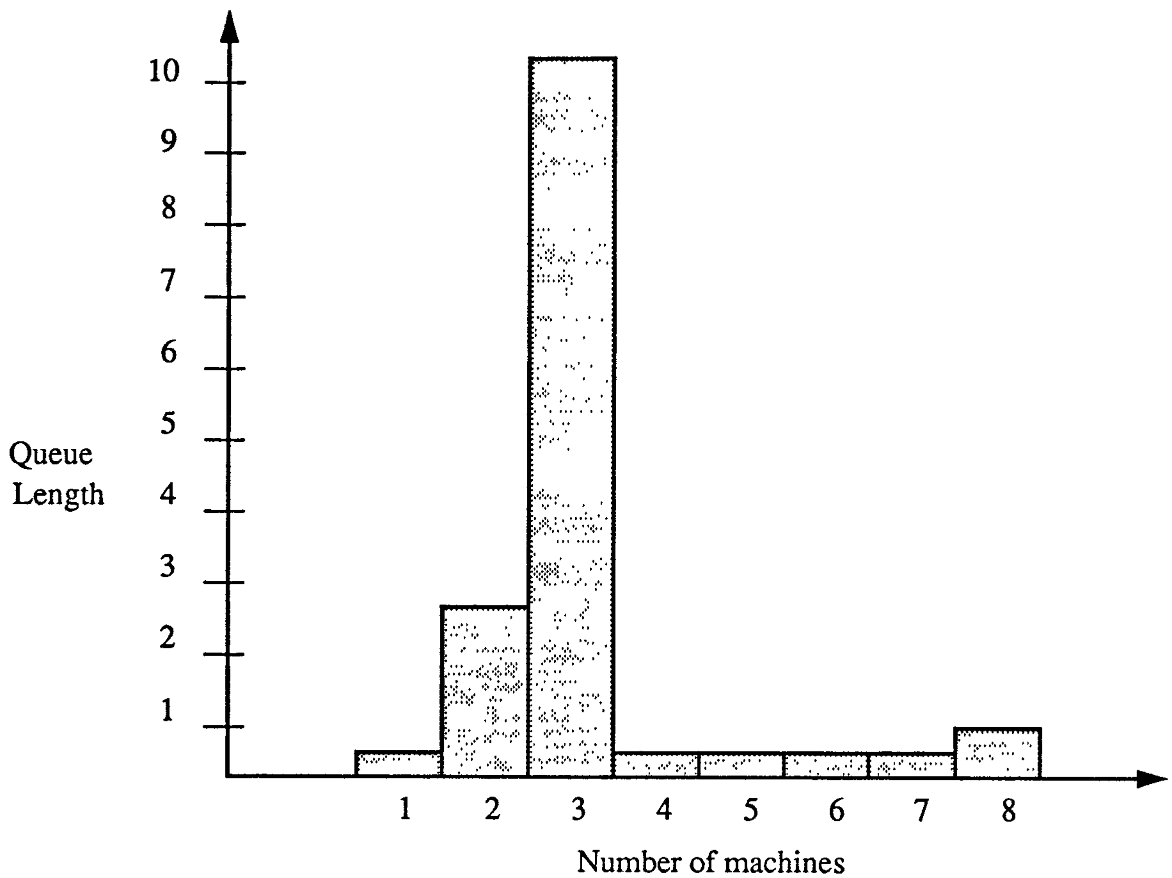


Fig 6.26 Exponential Distribution

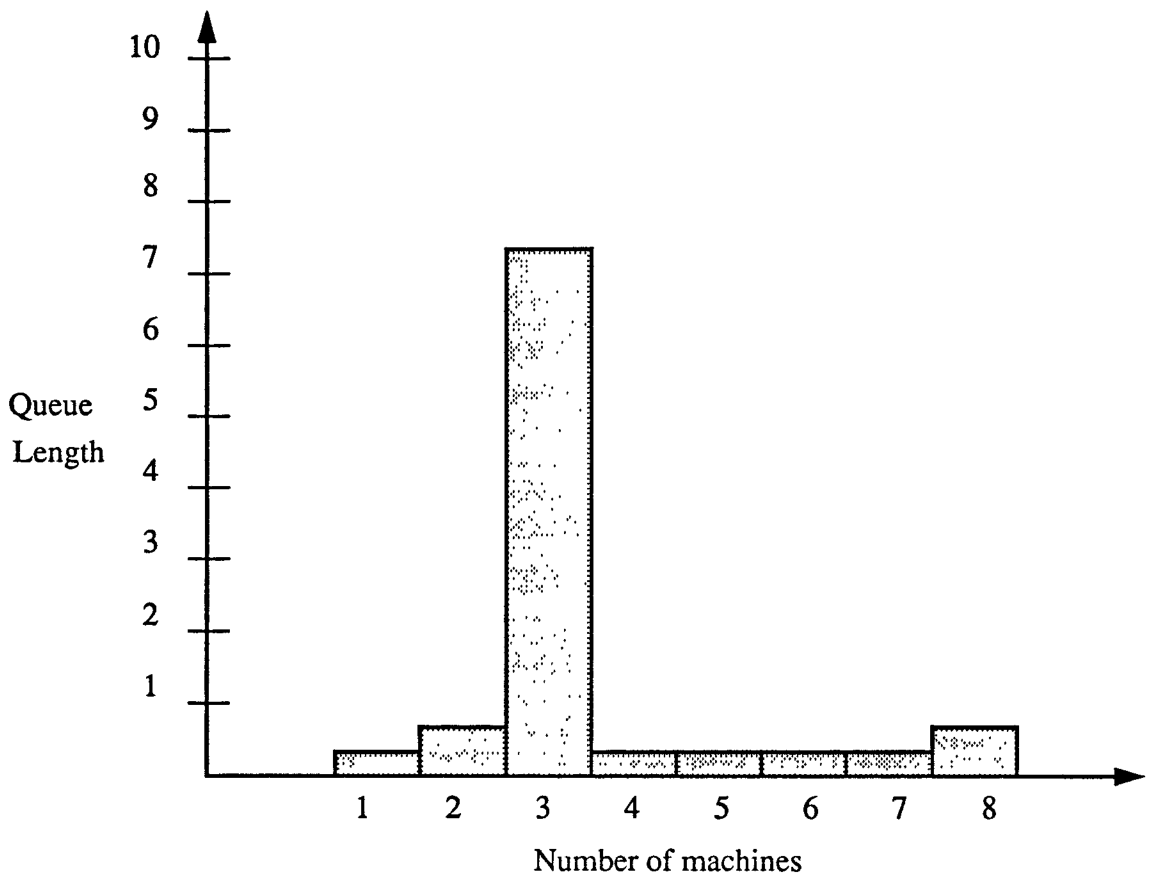


Fig 6.27 Uniform Distribution

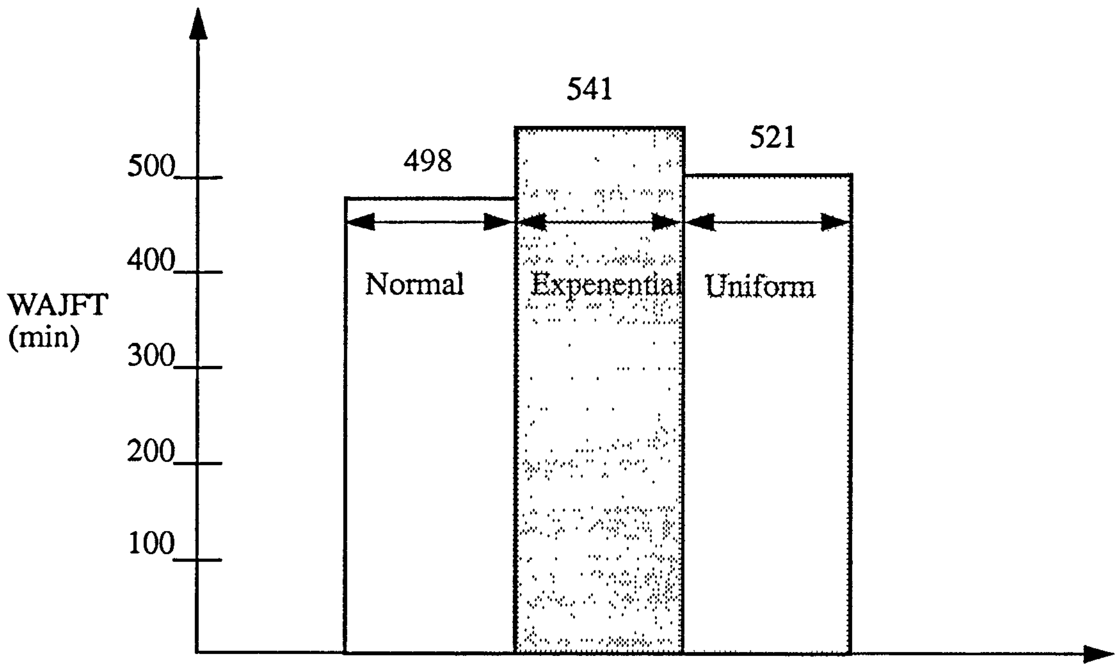


Fig 6.28 Comparison of Results

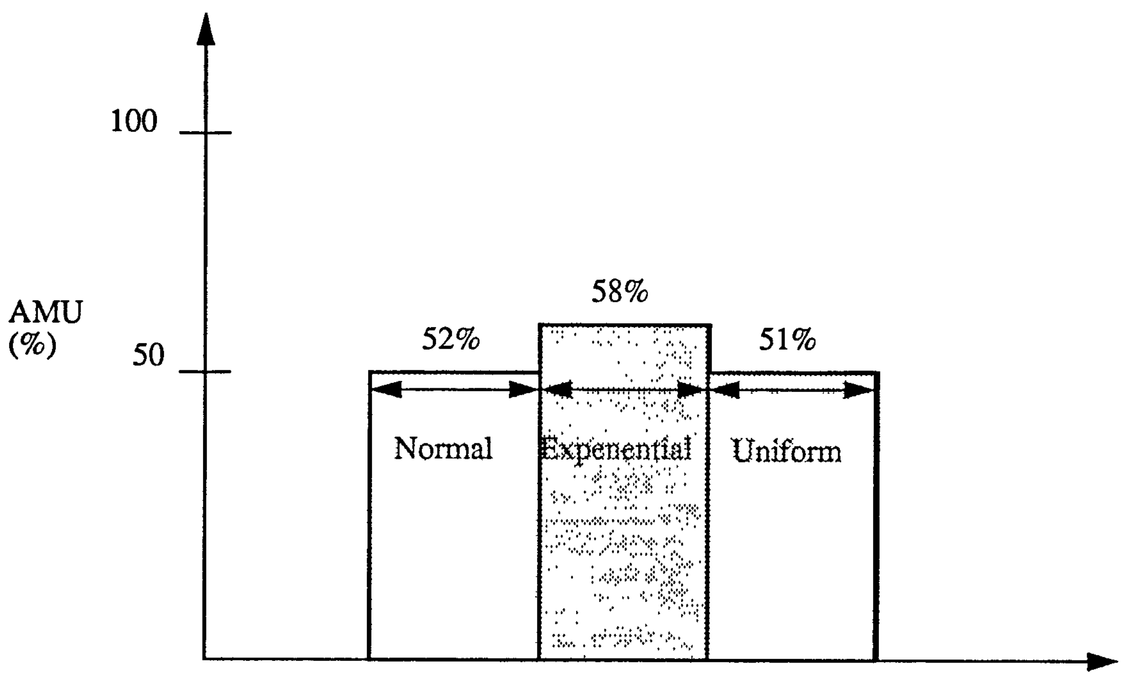


Fig 6.29 Comparison of Results

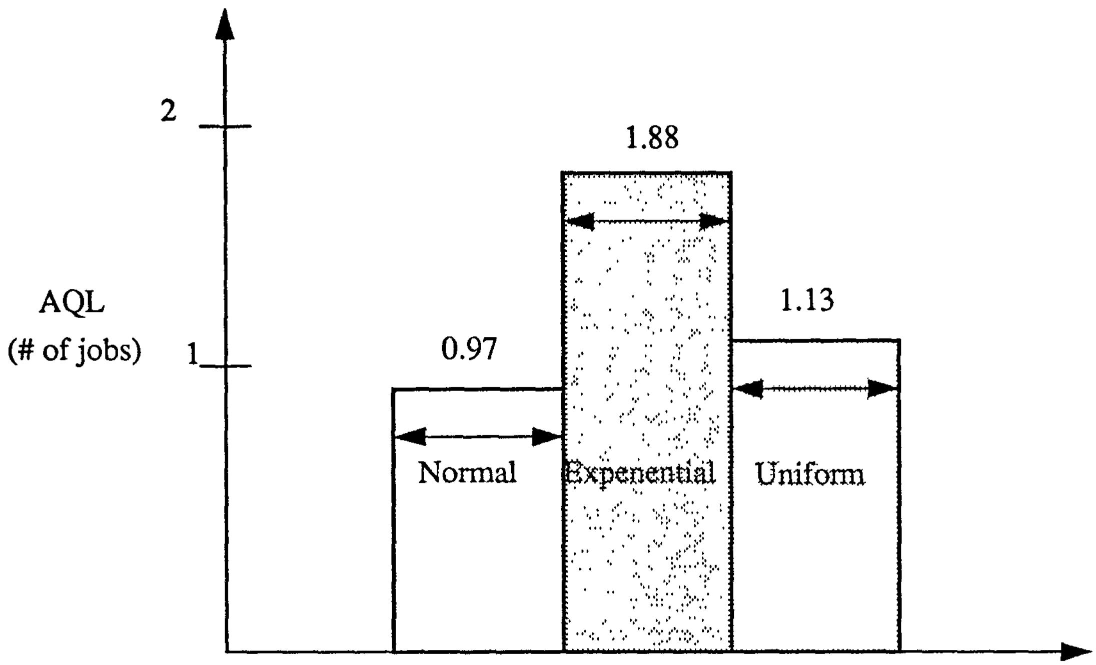


Fig 6.30 Comparison of Results

2. Average Queue Length (AQL) is 0.97 in case of Normal Distribution but higher in case of Exponential Distribution which is 1.88.

3. Weighted Average Job Flow Time (WAJFT) is minimum in case of Normal Distribution (498 min) but maximum incase of Exponential Distribution (541 min).

4. Machine No.3 has maximum Queue Length in each case.

5. Utilization of Machine number 3 is maximum in each case.

6. Minimum Machine Utilization and maximum Weighted Average Job Flow Time is observed in case of Uniform Distribution.

Different SIMAN Outputs and comparison of results are shown in figures from 6.16 to 6.30.

6.9 Conclusion

Effective use of technology is an important tool to achieve increased efficiencies. This study provides a basic insight to the simulation based integration of shop floor activities. This describes how simulation can provide the effective co-ordination of all significant components in an integrated manufacturing system. The implementation of a shop floor planning and control system is a pre requisite to establish an effective Computer Integrated Manufacturing system and simulation is an important tool to accomplish this. This claim is supported by the case study, which describes how shop floor management can use simulation on shop floor to maximize productivity and profitability. Maximum Average Machine Utilization (AMU), observed in case of exponential distribution but at the cost of maximum average queue length (AQL) and weighted average job flow time (WAJFT). Queue lengths can be minimized, introducing buffers between machines. Optimum allocation of buffers results in increased efficiency. Average job flow time can be optimized using alternate job routing.

BIBLIOGRAPHY

1. Martino, Rocco L., Ph.D., " Integrated Manufacturing Systems." Mc Graw-Hill Book Company, N.Y. 1990.

2. Compton, Dalen W., Editor, " Design and Analysis of Integrated Manufacturing Systems." NAE, National Academy Press, Washington, D.C, 1988.

3. Hordesk, Michael, " Computer Integrated Manufacturing Techniques and Applications."TPR, Division of TAB BOOKS Inc., Blue Ridge Summit, PA, 1988.

4. Kochan, Anna and Derek Cowan. " Implementing CIM Computer Integrated Manufacturing."IFS(Publications) Ltd. UK,1986.

5. Teichalz, Eric and Joel, N. Orr." Computer Integrated Manufacturing Handbook." McGraw-Hill Book Company, N.Y. 1987.

6. Engelke, William D.," How to integrate CAD/CAM Systems, management and Technology." Dekker, Inc., N.Y. and Basel, 1987.

7. Keinig,Daniel T.," Manufacturing Engineering,Principles for Optimization."Hemisphere Publishing Corporation, N.Y. 1987.

8. Lenz, John E.," Flexible Manufacturing, Benefits for the low-inventory Factory." Marcel Dekker, Inc., N.Y. 1989.

9. Fuchs, Jerome H.," CMS, The Prentice Hall Illustrated Handbook of Advanced Manufacturing Methods." Prentice-Hall, Englewood Cliffs, NJ 07632, 1988.

10. Chang, Tien-Chien and Richard A. Wysk., and Hsu-Pin Wang,"Computer-Aided Manufacturing." Prentice-Hall Englewood Cliffs, NJ 07632, 1991.

11. Groover, Mikell P.," Automation, Production Systems, and Computer Integrated Manufacturing." Prentice Hall, Inc., Englewood Cliffs, NJ 07632, 1987.

12. Hillier, Frederick S., and Gerald, J. Liebermann., "Introduction to Operations Research, 5th Edition." McGraw-Hill Publishing Company, N.Y. 1990.

13. Sartori, Luca G.," Manufacturing Information Systems." Addison-Wesley Publishing Company, N.Y. Oct.'87.

14. Riggs, James L.," Production Systems, Planning, Analysis and Control , Fourth Edition." John Wiley and Sons, N.Y. May, 1986.

15. Carrice, Allan. " Simulation of Manufacturing Systems." John Wiley and Sons, N.Y., 1988.

16. Hoover, Stewart V. and Ronald F. Perry ," Simulation, A Problem-Solving Approach." Addison-Wesley Publishing Company, N.Y. 1989

17. Tou, Julius T.," Computer-Based Automation." Plenum Press, N.Y. and London, Aug'1984.

18. Pegden, Dennis C., " Introduction to SIMAN." Systems Modeling Corporation, PA 16805, Nov.'1987.

19. Rathmill, K.," Control And Programing in Advanced Manufacturing." IFS (Publications) ltd, UK, 1987.

20. Rathmill, K.," Flexible Manufacturing Systems, Proceedings of the 5th International Conference (Nov.'1986)." IFS (Publications) ltd., UK, 1986.

21. Puente, E.A. and Nemes,L.,"Information Control Problems in Manufacturing Technology." Pergamon Press, N.Y., 1989.

22. McLeod, Raymond, Jr.," Management Information Systems, Fourth Edition." MacMillan Publishing Company, N.Y., 1990.

23. McGeough, J.A.," Computer Aided Production Engineering, Proceedings of the International Conference (Apr.'86)." MEP for The Institution of Mechanical Engineers.

24. Tulkoff, Joseph," CAPP, From Design To Production, First Edition." Society of Manufacturing Engineers, Dearborn, Michigan 48121, 1988.

25. Drozda, Thomas J.," Flexible Manufacturing Systems, Second Edition." Society of Manufacturing Engineers, Dearborn, Michigan 48121, 1988.

26. Hyer, Nancy Lea." Capabilities of Group Technology, First Edition." The Computer and Automated Systems Association of SME, Dearborn, Michigan 48121, 1987.

27. Hamed, K. Eldin and John, W. Nazemetz.," Computer And Industrial Engineering, An International Journal, Proceedings of the 11th Annual Conference

on Computers and Industrial Engineering, Volume 17, 1989."

28. Bertain, Leonard and Lee Hales. " A Program Guide For CIM Implementation, Second Edition." SME, 1987.

29. "Simulation Modeling Manufacturing & Service Systems." Published by Institute of Industrial Engineers,1987.

30. "International Conference On (CIM), Computer Integrated Manufacturing of the IEEE, 1988."

31. Volz, Richard A., and Arch W. Naylor.," Work Shop On Manufacturing Systems Integration." University of Michigan, AnArbor, 1985.

32. Grier, C. I. Lin," CIM Optimization." University of South Australia, Australia.

33. Das, K. Sanchoy ," A scheme for classifying Integration Types in CIM." Paper submitted to the International Journal of CIM, July '91.

34. Boaden, R.J and B.G.Dale," The Progress of a CIM Program in a multi-national company." International Journal of CIM, Vol. 2, 1989.

35. Jones, Albert and Edward, Barkmeyer and Wayne, Davis., "Issues in the design and implementation of a system architecture for computer integrated manufacturing." International Journal of CIM, Vol. 2, 1989.

36. Greene, Timothy J. Ph.D.," An Evaluation and review of CAPP Systems." International Industrial Engineering Conference Proceedings, 1987.

37. Kahan, Steven," Does MIS belong on the Shop Floor." Published in Automation, 1991.

38. Mackay Duncan," Road blocks to CIM." Published in Automation, 1990.

39. Vester, John and John Venckus," Systems Integration and Material Spine."Published in Industrial Engineering, 1987.