CHAPTER - I
SECTION-I
INTRODUCTION
Managers of manufacturing companies are being suddenly confronted these days with an array of new manufacturing systems to improve production efficiency. It may be material requirement planning (MRP), Kanban or Just-in-time production technology (JIT); or the latest approach - the flexible manufacturing system. As in many areas of business, choosing the best operations management technique requires making trade offs (1).

A revolution has taken place in operations management for improving the efficacy of the production system through the latest advanced approaches. Recently three major approaches have focussed the attention of operation managers, namely material requirement planning (MRP), Kanban or Just-in-time production system (JIT) and optimized production technology (OPT). As these three approaches are not enough, managers are confronted with new alternatives, with the emergence of flexible manufacturing systems (FMS).

S.C. Aggarwal (1) has provided the plant managers with a comparative insight and general assessment of the three principal systems along with the latest Flexible Manufacturing Systems (FMS).

Material requirement planning

Material requirement planning technique (MRP) provides for available purchased and company manufactured
components and sub-assemblies expeditiously to the next stage of production or for dispatch.

MRP works on the assumption of fluctuating demand and makes an effort to achieve nil stock out and concentrates on setting priorities. It requires that a precise demand forecast for each product is available and that each and every product or sub-assembly's bill of material is accurate.

Managers adopting the MRP approach are in a position to calculate in advance the requirement of each and every part on weekly basis and can identify in advance possible delays or shortages if any. Inventory control department, can reschedule the affected release dates for orders in order to try to meet the promised deliveries.

MRP requires that each and every employee be thoroughly and strictly disciplined about feeding up dates into the system. Without such adherence, the MRP System memory starts accumulating errors with regard to stock on hand, quantities needed, and when items are needed for specific parts. Every one interacting with MRP System must make all their decisions using system data at each and every step. MRP system appears to work the best for companies with mass production assembly lines and with a history of chaotic inventory situations.
Any where from 2000-5000 U S Companies today—mostly with annual sales exceeding $30 million are using MRP (1). As an elaborate information system, MRP focuses management attention on accurate records, which in turn leads to reduced inventories and improved consumer service.

Black and Decker (1) has achieved remarkable success using MRP. Being the world’s largest manufacturer of power tools, with yearly sales over $1 billion, it produces nearly 20,000 items. With MRP the company has improved its materials requirement planning, handling and record keeping. Further, it reduces engineering change orders, surplus and obsolete materials, components, and post—due receipts from suppliers. But to give the whole credit to MRP would not be proper. Black and Decker (1) managers and other employees planned and accomplished their mission intelligently and MRP did helped by producing reasonably correct and timely information. An article in the March 1984 issue of International Management (89) stated that some critics believe, “MRP is $100 billion mistake and 90% of MRP users are unhappy. They believe that companies using MRP and other computerized planning system have preserved high levels of inventories as usual”. Moreover, MRP requires tremendous amount of data inputs and is complex in character. It assumes unlimited capacity in all work.
whereas in reality some centres always behave as bottlenecks. This contradiction destroys the accuracy of MRP scheduling logic and makes it ineffective for capacity planning and control.

Kanban: Just-in-time

To Japanese managers, (1) Kanban or Just-in-time System is an approach for providing smoother production flows and making continual improvements in process and products. Kanban attempts to reduce work in progress to an absolute minimum. In addition the system constantly attempts to reduce lead times, work in process inventories and set up times.

Kanban's main objective is to obtain low-cost, high quality, and timely production. To achieve this, the system attempts to eliminate stock between the successive processes and to minimise any idle equipment, facilities or workers.

Kanban assumes that the production rate at the final assembly line is even. It cannot tolerate load fluctuations of more than 10% and it starts breaking down under larger deviations from average conditions. It also requires that the daily schedule for each part remains nearly the same everyday.

Kanban has its roots in employee motivation
wad assumes that: employees will perform to their full capability when entrusted with greater responsibility and authority, and will also co-operate with other co-workers when they fall behind as scheduled. Every Kanban workers has the right to stop the assembly line when he or she is falling behind or discovers a defective part or sub-assembly.

The Kanban approach keeps the set-up times and cost at negligible levels. In addition, the company's suppliers are supposed to act like extended storage facilities of the company itself.

The Kanban system requires strict discipline and cooperation among all categories of employees, along with new methods and procedures for manufacturing, planning and control. Kanban has been mostly used for man produced items in Japan, Europe and more recently in North America. It emphasizes small lot-sizes as the system requires short lead times, which translate into small inventories at every stage. This is achievable because a chain of move tickets connect all stages from suppliers to retailers and companies never need additional paper work for planning and control.

Kanban is a pull system. The user department pulls the parts or sub-assemblies from the suppliers department. No extra production or inventories are permitted. Moreover, workers experience the satisfaction of being in
charge of the system and making useful improvements in the company's operation.

Japanese companies that have used Kanban for five or more years are reporting close to a 30% increase in labour productivity, a 60% reduction in inventories, a 90% reduction in quality rejection rates, and a 15% reduction in necessary plant space (1).

General Motors (1) has used the Kanban system since 1980 and has since slashed its annual inventory-related cost from $8 to $2 billion (1). Alfa Laval, a Swedish company that uses Kanban has reduced its throughput time from 40 to 8 weeks. Appliance makers like General Electric, Westinghouse, RCA and others are also experimenting with Kanban in some of their plants. But none has achieved an ideal system on a par with Toyota’s, the originator of Kanban (JIT), but most are reporting some success in reducing inventories and production lead times.

Not every application of Kanban is a success story. United States users are encountering many problems in implementing the approach, for example far-away suppliers, poor quality of parts, unreliable freight system and resistance from workers.

Optimized production technology

Optimized production technology (OPT) system calculates the near-optimum schedule and sequence of
operations for a manufacturing company's work centres, taking into account priorities and capacities. Advocates claim it can simultaneously maximise the use of critical resources and the plant output and minimises work-in-process inventories and manufacturing lead times or throughput times.

OPT approach determines priorities for each operation using a weighted function of a number of important criteria, like advantageous product mix, due dates, necessary safety stocks and use of bottlenecks machines. Actually OPT uses a set of "management coefficients" which help to determine the duration of the fixed intervals and the optimal batch size for each sub-assembly or components being processed at each machine or recourse.

OPT is a proprietary computer software package which accepts data regarding production requirements and manufacturing facilities normally available from the plant records. The system then tests the existing work load and spotlights capacity bottlenecks. OPT uses its algorithm to schedule individual jobs efficiently, while taking care of the existing bottlenecks.

Developers of this system claim that their process breaks down a total production plan into separate stages and searches for the best possible detailed schedule. Since production data are rarely accurate, no
schedule can be perfect. Further, OPT originators stress that managers must change their old ways of running things - staggering lunch hours, so that bottlenecks machines are operating constantly, revamping the company's cost-accounting system to reflect realistic operational and inventory costs, and allowing some workers to stand idle at times when no demand exists for certain components. The system's creators claim that OPT uses limited amounts of data, most of which are readily available. They also stress that it makes use of an ideal batch size for each product at every production stage. OPT does require, however detailed information about inventory levels, product structures, routing, and set up and operation timings for each of and every procedure of each product. The developers claim that only the bottlenecks stages need to be planned in very general terms. They also assert that the system takes into account scores of factors that control production efficiency, like plant capacity, work in progress, set up times, substitutions, overlapping among process batches, sub-contracts, and safety stocks. The program plots these factors on a nine dimensional graph and determines a near-optimum combination. The developer's claims for the system have been questioned by academics, competing consultants and a few users.

In companies employing about 500 people, OPT can be implemented within two or three months. For minor
disruptions, OPT schedule need not be rerun (Theoretically MRP requires rerunning after each disruption). OPT is quite fast, it can produce one day's schedule for several hundred workers in minutes.

About 100 companies worldwide have bought OPT software packages. Most were facing serious capacity or production lead-time problems. Each had a very large variety of products that require processing in anywhere from 3 to 40 process centres.

M and M/Mars Candy Company was one of the first OPT users. It reports a 5% increase in its overall output and up to 15% increase in the output of some of its process centres (1). GE's engine plant in North Carolina has successfully used OPT to generate efficient production schedules (1). In three months, it made the system operational and reduced its work in progress by 30%. This plant has nearly halved its inventories, from 140 day supply to 80 day supply.

Unlike MRP and Kanban with OPT management doesn't have to worry about involving managers or changing employees' attitude. Several OPT users however emphasise that implementers must be creative in modeling the materials flows and must conduct multifacet analysis to identify minor practices that slow movements of parts and components through the plant. As no US Company has
used OPT for more than four years, its long-term effects are unclear. The program certainly taken care of established minimum stock levels, but it can create work-in-progress levels that may be nearly 20 times higher than normal. So far, most OPT's success stories come from its developers or from a few enthusiasts. To be objective and confident about any evaluations, we must wait several years for limitations to surface.

As time passes, more and more user companies will certainly report them.

Flexible manufacturing systems

Several machine builders in Japan, United States and Europe are trying to develop flexible manufacturing system (59). These systems are supposed to incorporate planning and control of their machinery operations within their computerized integrated control data systems. These data systems have built-in-production planning routines; FMS parts programming routines; and materials handling routines for parts, tools and accessories; and stock control in the form of separate modules.

The system integrate such functions as loading, unloading, storing parts, changing tools automatically, machining and data processing activities of the manufacturing processes into coordinated production centres.

The FMS's are designed to provide much diversification of parts or assemblies in batches. They are
supposed to obtain greater productivity from machines. Generally production utilization of most general purpose machines is between 6% to 30%. These systems are expected to enhance machinery utilization to 80% or even 90% level. Despite all the computerization levels, the manager still plays an important role in defining company objective for the system which may also include maximization of quarterly profits.

In reality, it would be almost impossible to achieve these objectives simultaneously. Once managers have selected their performance criteria and defined limitations and work rules for their FMS installations, the computerized integrated control systems take over and can prioritize and schedule individual orders (Production batches) in a near optimum manner. FMS integrated control systems not only regulate the times when machine operate but also the flow of parts. Conceptually, FMS installations are as close to an automatic factory as one can imagine. They are supposed to provide unprecedented levels of customer service, lower unit costs, reduced production lead times and more flexibility and product variety than other systems.

Estimates of FMS applications throughout the world vary widely from 40 to 300 (1). Some of the well-known applications are at John Deere Waterloo Tractor Works, Cummins Engine Plant, Chrysler, J.I. Case Company,
MaiMf Ferguson, Xerox and others in the United States; Brothers Industries, Mito Hitachi, Toyota Machine Works and Toyota Motors and few others in Japan; Renault Vehicle Industries, Citroen Line Wotan, and Peugeot S.A. in France; and Fiat body work assembly in Italy, along with a few others in Sweden, Russia, East Germany, and Czechoslovakia.

Each of these installations is only a few years old but the companies have invested millions of dollars in each FMS and are supporting them enthusiastically. Most FMS users reports are positive. Of course, each new installations will always have some bugs that needs to be flushed out.

Technically and operationally flexible, manufacturing systems are still in their adolescence. In recent times most of the studies are being funded by the governments of various countries and their ultimate aim is to derive an FMS system that will need no work force, whatever will be extremely flexible in terms of product and volume mix, and will provide high quality, low cost-output with very short lead times.

Choosing a System and making it work

Even if executives can ignore the complex design, huge input requirements, and multi-million dollar's investments in each of these systems, one cannot overlook
the real constraints in terms of the working habits of employees, who must operate them. Successful companies have developed in-house competence in working with these systems. Initially they have used experts to train employees, after which each company has struggled on its own to solve problems that surface constantly.

During the last 25 years companies and countries have spent billion of dollars on smarter softwares and faster computers for automating the flow of materials through manufacturing stages. Each new system's developers initially exhibited great enthusiasm, but as users encountered serious operational difficulties and could not achieve promised results, proponents began to loose their zeal.

If a common obstacle exists: successful implementation of computerized production system, it's getting employees to perform appropriately. Among the hurdles are: How can managers keep employees who interact with systems disciplined and motivated? How can companies be sure that employees are constantly feeding the system with up-dated information that results from hundreds of unplanned disturbances in the field? How can management get workers to accept changes in procedures, organizational structures, paper work, cost accounting and so forth?

Indirectly the Kanban (JIT) system addresses these problems, which is probably why most of its users
are reporting successful results. Kanban (JIT) is a simple and transparent system. Employees are responsible for making it work, and results indicate that they are willing to accept such a challenge. MRP offers no challenge to employees but requires that they be extremely disciplined and committed at all levels - which helps explain why 90% users are unhappy with results (1).

OPT tolerates minor disturbances and requires moderate discipline and limited data accuracy. The contract rules its consultants impose force top executives to make procedural, cost-accounting, and work method changes, which may explain why problems with employees get resolved indirectly. Therefore, to a limited number OPT users seem to be reasonably happy with the system.

The evidence so far indicates that the design and applications of FMS are headed towards resolving the other systems problems, when perfected it should be ideal for providing the efficiency and flexibility essential for survival and growth in today's extremely competitive market place. FMS installations are expressely built to eliminate most employees operational problems and therefore may someday replace all the other operations planning and control systems.

Kanban (JIT) system being the most successful
of all the present day systems, is very simple and transparent to understand and implement, the researcher will focus his attention on JIT in building the "Simulation model of an integrated business organisation for decision making". India being a vast and diversified country and much computerization has not taken place yet for successful adoption of all other systems. It is feasible that Kanban (JIT) which require less computerization is the answer to the system to be adopted in Indian conditions. The following sections review the literature on Kanban (JIT), simulation modeling, applications of simulation in USA industries and forecasting the essentials of the production-distribution system network model to be built.
SECTION - II

SURVEY OF JUST-IN-TIME DISTRIBUTION
The first article on Just-in-Time production system appeared in 1977: Sugimori (80) discussed the production system implemented at Toyota by a Vice-president. This was designed to attain low cost with minimum amounts of equipment, materials, parts and lost time to maintain production.

The Toyota Production System and Kanban system introduced in this paper was developed by the Vice-president of Toyota Motor Company, Mr. Taiichi Ohno and it was under his guidance that these unique production systems have become deeply rooted in Toyota Motor Company in the past 20 years. There are two major distinctive features in these systems, one of these is the 'Just-in-time production', a specially important factor in an assembly industry such as automotive manufacturing. In this type of production "only the necessary products, at the necessary time, in necessary quantity" are manufactured and in addition, the stock on hand is held down to a minimum. Second, the system is the respect for human system where the workers are allowed to display in full their capabilities through active participation in running and improving their own workshops.

Mondon (49) paper gives information on the Toyota Production System in particular. Mondon also (48) discusses how the Toyota production system was developed
and is now adopted by many Japanese companies. He observes that the main purpose of this system is to reduce cost surrounding production process. This system also helps to increase the turnover ratio of capital (i.e. total sales/total assets). In other words it improves the total productivity of a company as a whole.

An other article of Monden (50) observes that the ultimate purpose of Toyota production system is to increase profits by reducing cost. He observes that cost reduction can be achieved by eliminating waste, especially by doing away with unnecessary inventories.

Pagel (54) discusses a management system which has been used in Japan's Toyota Motor Company for many years in particular. He observes that the system is applicable to the assembled goods industry and is widely used in such circumstances in that country. It extends well beyond production and inventory control and incorporates a number of features of a decidedly Japanese nature. Dominant among these is Just-in-time Production which is examined at some length. Also described is Kanban, and several of its elements, which is an essential aspect of Just-in-time production.

Schonberger and Schiederjans (66) have discussed JIT in general. Western notions about inventory control revolve around economic order quantities and buffer stocks that are aimed at avoiding running out of stock but it
results in high inventories and long lead times. The inventory model as formulated by Schonberger and Schiederjans (66) is recast into principals: The lot size principal is simply to keep cutting it - and cut set up times as partial justification. The buffer-stock principal is also to keep cutting - and solve the exposed quality, equipment and other problems thereby exposed.

New revelations about inventory control suggest that the following may be safely said to management, in practically any manufacturing company: Whatever your purchase and manufacturing lot sizes are, they are too large, what ever amounts of buffer stock you carry for your own "protection" they are also too large.

The foundations of classical inventory control weaken as western industry comes to understand the very different approach, developed in Japan, that is often called the just-in-time system. The just-in-time (JIT) approach calls for slashing production and purchase lot sizes and also buffer stocks (but incrementally, a little at a time, month after month, year after year). The result is sustained productivity and quality improvement with greater flexibility and delivery responsiveness.

Western inventory management is rooted in the notion of ordering in economic order quantities, and staging buffer stocks between processes to keep production
from stopping when problems occur. These inventory concepts are unsound. Obstacles to converting to the new approach, are minor - especially when just-in-time production is viewed as a long term series of cuts in inventory and related productive resources followed by the resolutions of problems.

Hayes (25) in his article discusses the positive features of Japanese manufacturing basis. He opines that Japanese succeed not by using futuristic and sophisticated techniques but by paying attention to manufacturing basics. Japan's rapid evolution into a major industrial power has aroused in the U.S. managers both awe and wish to discover the secret of Japanese manufacturing success. Contrary to popular opinion, this evolution has not come about through the use of like quality circles and advanced technologies like robots. What Japan has created is the factory of the present, operating as it should. Japanese managers have never stopped emphasizing the basics. To them, every stage of the manufacturing process - from product-design to distribution - is equally important. They constantly work to improve equipment design, inventory control systems, and work still through cooperation at all levels. The ultimate goal Prefect products and error free operations.

Jackson (31) describes the JIT System successfully
used in many Japanese companies, and the importance of co-ordination and of inbound transportation for North American or European implementation.

Rice and Yoshikawa (62) review the Kanban system and relate Kanban to MRP (Their Kanban system is what other authors call Just-in-Time System). Both Kanban and MRP depend upon bottom participative management within each company. MRP uses time horizon planning while Kanban features shop-floor control. Most Japanese industries applying the Kanban System are set up on a general one year master schedule, a one to two month horizon for the detailed production schedule, a 99 per cent fixed ten day production schedule and a daily schedule.

Martin (42) has applied Material Requirement planning to distribution resulting in Distribution Requirements Planning (DRP). Martin (42) and Stenger and Cavinto (74) discuss the benefits of extending MRP to the "outbound side".

Ebrahimpour and Fathi (17) generated "Dynamic Simulation of a Kanban Production inventory system model". This article presents a simulation model of a Kanban inventory system developed in the simulation language DYNAMO. The problem addressed is the effect that implementation of Kanban has on the level of work in process inventories. The difference between Kanban and traditional inventory management system is discussed and
a model of a production line is described using the Kanban technique. The simulation runs compare inventory behaviour in three environmental conditions, cyclic demand, steady growth and gradual reduction of cards during stable demand. The conclusions are (1) reduction of cards does not reduce work in process inventory and (2) In cyclical demand environments, work in process inventories may increase due to delays inherent in the production line structure.

Huang, Reese and Taylor (29) describes "A Simulation Analysis of the Japanese Just-in-Time Technique (with Kanbans) for a Multiline, Multistage Production System". The authors describe how the Japanese "Just-in-Time" distribution can be applied in American conditions with some modifications. The Japanese "Just-in-Time with Kanban" technique reduces in-process inventory to absolute minimal level, in concert the Japanese belief that inventory is an unnecessary evil. Due to the success of Japanese firms that employ this type of system, American firms would like to import this technique and emulate Japanese successes. But the Japanese success may be attributable not only to the Just-in-Time with Kanban technique but also to the production environment in which the technique is employed. The paper (29) describes the simulation analysis for a multilime, multistage production system in order to determine the adoptability to an American Production environment that might include such
characteristics as variable processing time, variable master production scheduling and imbalances between production stages. The results have practical implications for those firms considering adoption of Japanese Technique.

The simulation Model presented in this paper is used to explore effects of factors such as variable processing time, variable master production schedule and imbalances between production stages in Japanese JIT System. Exploring such decision making situation within a simulation frame work, one can determine the extent to which an American production manager must alter the existing production environment in order to incorporate the JIT system, the time-frame that implementation must encompass, the results that can be expected from a JIT system, the production that might arise from implementation and whether or not a JIT system should be implemented at all.

Lee and Maling Ebrahimpour (18) discuss Just-in-Time Production System in context to some requirements for implementation of Just-in-time Production System. The authors observe that many consider that Japanese manufacturing management techniques are among several factors which have contributed to Japan's superior quality and high growth rate of productivity. Just-in-time (JIT) is one of the best known Japanese Production management systems amongst management in the western
industrialised nations. In this paper the JIT manufacturing system and its key features are discussed. The important prerequisites and factors that are required for implementation of JIT in Western Industrialised nations are then elaborated on. It is concluded that proper implementation of the JIT production system requires many changes in the organisation; yet successful implementation results in improved productivity and higher quality.

Ibrahim Nisanci and Nicoll (30) emphasised the need of an integrated plan to organise and administer the project for companies striving to implement JIT operations. Just-in-Time is viewed as a level of perfection achieved by continuous elimination of the wasteful use of resources. Its major objective is the reduction of working capital, administrative and manufacturing costs.

Targets set by JIT, such as zero set-up times, zero inventories, zero defects, zero breakdowns, etc., are difficult to reach, therefore JIT requires a relentless improvement process and the participation and commitment of all departments and levels within an organisation.

James H Bookbinder and Timothy Locke (7) have generated a Simulation model of "Just-in-Time distribution". Just-in-Time (JIT) production has been a
subject of considerable research in the past few years. The Japanese were the first actually to use JIT systems rather than the traditional economic order quantity inventory system or the more recent method of Material Requirement Planning (MRP). Considerable savings in inventory holding costs, faster spotting of defective producing stations and improved quality control have been observed using Just-in-Time production system.

Section III comprises survey of literature on simulation modeling.
SECTION III

SURVEY OF SIMULATION MODELING
The scientific method is our principal tool for prediction and estimation. Among the steps usually identified in this method, we find close observations of the physical phenomenon, creation of theory or a model which explains the observations, prediction of observable from the theory by using mathematical or logical deductions and performance of experiments to test the validity of the model.

Sometimes it is not possible to follow this procedure for a given problem or system. It may not be possible to observe the phenomenon in its desired environment. This is true of studies of the thrust of rocket motors for use in interplanetary space. The phenomenon or system may be too complex to summarize in a compressed mathematical formulation. It has not been possible for example to reduce the operation of a large business activity to a few simple equations. Analytical techniques may not exist for solving the mathematical formulation once it has been achieved.

As far as business industry are concerned, with which we are primarily concerned in the course of this research work, it is pertinent to add that with the increasing population influx, the challenge faced by business industry are many fold. As such commerce industry, and government have become exponentially more complex since world war II. One obvious reason is the
tremendous increase in the number of variety of products and services being made available. In today's world of diversification, it is rare to find a manufacturer who produces and distributes only one product. As a consequence of this diversification and rapid growth have business/tremendously complex organisation and control problems.

Since the fifties, the computer has been, without question a key factor in improving management decisions. However computer usage has been limited primarily to provide management with quick and accurate access to status information, thereby making existing methods of decision making more effective.

Managers, who are living in a world of rapid change and extensive interactions, must continually improve their own decision-making skills or end up reacting to crisis instead of controlling activity. Apprenticeships and experience are not enough, now-a-days judgement and intuition are barely put into use before the change occurs. A formal and efficient technique is needed to augment the manager's experience. The technique must be formal that is capable of precise-documentation, so that it can be learned quickly and applied to new situations. The technique must be efficient so that its cost does not increase in proportion to the complexity of the situation.
Computer simulation is a technique that will fulfill these needs. Computer simulation is a formal decision making process that is adaptable to the complexity and change of modern business and can be developed and communicated efficiently.

Simulation models of operation systems have been growing rapidly and promise to become a dominant technique for assisting management in the decision-making process for day-to-day problems, as well as for comparing basic alternative of operating policy. With simulation models, we can determine the effects of dozens of alternative policies without tampering with the actual physical system. Business and industry have already made important applications of the simulation technique, ranging from models of relatively simple waiting line situations to models of integrated systems of production.

Simulation Analysis was initially developed by Von Neuman and Ulam, nuclear physicists who applied this mathematical technique in solving a category of nuclear-shielding problems which were too expensive for experimental solution and too complicated for analytic treatment. Monte Carlo simulation is the code name given to this technique. Originally the concept referred to a situation in which there was a difficult non-probabilistic problem to be solved and for which a stochastic process may be invented which has moments or distribution satisfying the relation of the non-probabilistic problem.
Warren Alberts (60) of United Air Lines reported a model of an air line maintenance facility in which 100 days of operations are simulated in less than 12 minutes of computer time. Brown (60) discusses a general purpose inventory control simulator. The simulator makes it possible to evaluate customer service, the number of orders placed, the production work load and the total investment for the comparison of alternate system of control.

Feorene (19) of Eastman Kodak Company has published reports of a machine maintenance simulation which makes it possible to determine the optimum number of maintenance mechanics for various conditions.

Row (64) developed a job shop simulator and used it for evaluating alternate dispatch rules for the General Electric Company. Forrester (21) has developed dynamic simulation models of the Sprague Electric's Company's production distribution system which show time varying effects of changing market conditions and various alternate policies. The most traditional use of simulation has been in the engineering sciences where analogue simulation devices have long been used for scientific prediction of system performance.

More recently the whole hierarchy of space medicine and human engineering of space craft has been
viewed from the simulation view point. Large scale digital simulations have been performed at several agencies. At Rand, the Modem and Super Straw models were early simulation models. The Air Battle Analysis division at Headquarters USAF has applied the RAND Air Battle Model to study the complicated interactions of total air warfare.

Restricting our approach to the literature survey of simulation models to business industry, various authors have contributed extensively in popularising this technique. A brief description of the survey of literature on simulation models and the applicability of simulation in business industry is given in the following pages.

Charles, P. Bonine (6) focussed his attention on "Simulation of information and decision systems in the firm". The report describes a simulation model of a hypothetical business firm. The model is a synthesis of some of theory from disciplines of economics, accounting, organisation theory and behavioural sciences - all within a setting of traditional concepts of business practice. The purpose of the model is to study the effects of certain informational, organisational and environmental factors upon the decisions of a business firm.

Lawance Jones (33) of the centre for Drug Analysis U.S. Food and Drug Administration developed a
digital computer model that simulates laboratory operations and production scheduling at the centre for Drug Analysis. The model based on established empirical relationships between laboratory personnel, the number of laboratory samples awaiting analysis and the number of samples which will be completed during ensuing time periods. The developed model was then used to predict production for succeeding periods.

Christophel, Dealy and Paul, Finlay (12) generated a simulation model of a dispatch department. The operations of the dispatch department of a manufacturing organisation have been analysed in terms of matching the labour supply to the labour demand as determined by customers' orders. The problem differed somewhat from those traditionally associated with dispatch departments, as set up cost and company policy resulted in high stocks being carried. In this context service level did not refer to the ability to supply a customer from stock, but to the proportion of orders processed within a specified time interval. The final outcome of the study was an aid to decision making consisting of a family of curves of service level against the maximum acceptable time allowed to process an order.

G Southern (77) contributed an article which concerns with teaching technique of applying computers in production management and manufacturing system simulation. It employs a well proven teaching package to demonstrate
the technique of computer aided production management (CAPM) by means of manual simulation.

Mohanty and Chander Sekhar (46) have generated a simulation model of 'Production-Distribution System'. The problem is concerned with a single manufacturing enterprise producing varieties of products which are being distributed through a set of regional warehouses. The operations of each regional warehouse in the distribution system is considered to be quasi autonomous in the sense that the decentralisation is generated to the extent of formulating and operating their own cost structure and transportation modes. For the production subsystem there is a need for aggregation of regional ordering policies to take advantage of the single manufacturing facilities. The boundaries of both subsystems are highly interactive. The simulation approach suggested in this study highlights the casual behaviour of the interesting boundaries and formulates a feed back control model, in order to derive the various operational parameters of the total system. The effect of disturbance of the operational parameters on the total system behaviour has been studied through experimental design and analysis of variance.

S.A. Starbird and K. Ghiasi (78) generated simulation Model of a Multiproduct Tomato Processing Plant. The network based on simulation language SLAM
was used to model a proposed tomato processing operation. The model evaluates the feasibility of the proposed plant design in meeting market share requirements and the effect of various scheduling alternatives on the proposed profitability. The results indicate that the proposed design will meet market share requirements and that scheduling based upon raw products quality will increase profit by $18,000 (12.8%) over net income earned from a scheduling policy.

More recently R.P. Mohanty and A.M. Marathi (47) in yet another article generated a Simulation model for procurement-Production Distribution System. The article describes the development and use of a simulation model for studying the problems of the "Procurement-Production-Distribution" System of a manufacturing company engaged in the multi-stage production of many products. The Simulation model described is conceived from the casual and interactive behaviour of various interrelated activities. A direct feedback method of control has been incorporated to explore the effect of disturbance of operational parameters on the total system behaviour. With the increasing uncertainties about the business environment there is a need to respond more quickly and positively to various parameters which effect a business. The simulation model presented may be of some value in helping operations managers to explore and crystallise strategy alternatives.
SECTION - III-A

THE APPLICATION OF SIMULATION IN INDUSTRIES IN USA
David, P. Christy and Hugo, J. Watson, 1983 (13) carried a survey of non-academic users of computer simulation. They explored such issues as interest in simulation as a method of analysis, the functional areas which use simulation, the departments where simulation models are developed, the method of selecting a programming language for coding a simulation model, the popularity of various programming languages for simulation applications, and problems associated with the application of simulation. Current practice for measuring the effectiveness and suggestions for improving the use of simulation are discussed.

A number of previous studies have also found simulation to be one of the most effective management science methods in use today (Watson 1978 (87), Green Newsome and Jones 1977 (23), Shannon and Biles 1970 (70), Hovey and Wagner 1958 (28).

Watson and Marret 1979 (86) conducted a similar survey of nonacademic TIMS/ORSA members as of Christy and Watson 1983. They explored the major problems in implementing management science models. In this survey, they enquired about the major problems in implementing simulation models. While these are different questions and were asked at different times, a comparison of responses is interesting (Table 1.1).
The survey of 1983 (13) found a significantly smaller percentage of respondents indicating problems in selling simulation as a method of analysis to management (16% to 35%). This is possible due to several factors. First, organisations have reported good success in their use of simulation (Watson 1978) (86) and this undoubtedly creates a climate of acceptance for simulation. Also because simulation models reflect the logical relationships between the components of a system and often do not use sophisticated mathematical and statistical techniques, they tend to be relatively easy to understand by non-quantitative personnel. This may also be the reason that a significantly smaller percentage of respondents reported problems in defining and modeling problems for simulation applications (2% versus 19%) implementation problems.

<table>
<thead>
<tr>
<th>Problem Description</th>
<th>1979 Survey of MS/OR Users</th>
<th>The Survey(1983) of Simulation Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selling management science methods to management</td>
<td>33%</td>
<td>16%</td>
</tr>
<tr>
<td>Lack of quantitative education of top and middle managers</td>
<td>34%</td>
<td>40%</td>
</tr>
<tr>
<td>Lack of good data</td>
<td>32%</td>
<td>23%</td>
</tr>
<tr>
<td>Lack of time</td>
<td>23%</td>
<td>29%</td>
</tr>
<tr>
<td>Lack of end user education</td>
<td>22%</td>
<td>30%</td>
</tr>
<tr>
<td>Hard to define and Model problems</td>
<td>19%</td>
<td>2%</td>
</tr>
<tr>
<td>Payoff unsophisticated is good enough</td>
<td>16%</td>
<td>6%</td>
</tr>
<tr>
<td>Personnel shortage</td>
<td>12%</td>
<td>2%</td>
</tr>
<tr>
<td>Poor reputation of management scientist as problem solvers</td>
<td>11%</td>
<td>16%</td>
</tr>
<tr>
<td>Individuals feel threatened by MS/OR professionals and their techniques</td>
<td>10%</td>
<td>19%</td>
</tr>
</tbody>
</table>

*Statistically Significant difference at α = 0.05

Table 1.1: Comparison of 1979 and 1983 study.
Sources: (13)
Yet in another survey by F. Nelson Ford, David A. Bradford, James F. Cox and William N. Ledbetter (20), "Simulation in corporate decision making then and now" presents the results of a 1985 study, which replicates a 1975 study of Cox, Ledbetter and Smith (1977) (15) and attempts to measure the use of simulation modeling to support decision making in major U.S. corporations. Specifically, the purpose of the study was to (1) measure the development and use of simulation models at all levels of decision making (operational, tactical, and strategic); (2) examine the use of simulation within each functional area; (3) identify specific application areas within each functional area where simulation is being used and (4) compare this study's results with those from the Cox, Ledbetter, and Smith (1977) study (15).

Of the common management science techniques (e.g. mathematical programming, queuing theory, network models), system simulation is one of the most widely used aids in management decision making (Cox, Ledbetter and Smith 1977 (15), Ledbetter and Cox (37) 1977.

The study reveals that two different questionnaires were developed and administered to the firms in the 1985 Fortune 500 listing, half of these firms were randomly selected to receive questionnaire A; the remaining received questionnaire B. Questionnaire A examined the relative degree of simulation use at various levels of
decision support and in various functional areas of business. Questionnaire B measured the application of simulation in specific areas of decision support.

In the earlier study, the overall response rate was 35.2% compared to 14.4% (usable responses only) in this study. In addition to the usable responses offered 22 unusable questionnaires were returned and 22 other corporations responded with a letter or note. Two categories of information returned in both usable and unusable responses offer probable explanations for the lower response rate. First, several firms responding by letter explained that, because of the large number of surveys received in recent years and the resources required to respond, their company had a policy of not responding to any such survey. Second, several respondents, representing both usable and unusable responses, indicated that responsibility for management science activities was not centralised but was diffused to various units within the organisation. Simulation models are used at all levels of management, examples include corporate simulation models at the strategic level, financial simulation models at the tactical level, and inventory and scheduling simulation models at the operational level. Also, the widespread implementation of computer-based information systems throughout the firm creates an environment which hastens the use of simulation models to assist
managers in decision making. The evolution of decision support system (DSS) in particular provides a vehicle for the application of management science techniques within the firm, a vehicle which overcomes many of the problems, traditionally associated with the implementation of such techniques. Locating an appropriate respondent who would have knowledge of the use of simulation throughout the organization, if one existed was therefore difficult if not possible.

The study indicates regardless of the lower response rate is cause for caution and somewhat limits the generalizability of the results. On the other hand, the results do represent actual responses from 72 of the 1985 Fortune 500 firms and are therefore indicative, to some degree, of the use of simulation models by members of the population. It is also interesting to note that this response rate is similar to that reported by Kindered studies of Fortune 500 population (Green Newsome and Jones 1977 (23), Schmata and Kathwala 1986 (65)).

Respondents were asked to rate their use of Simulation techniques on a five-point Schale (where 1 = never and 5 = very frequently) for each level of decision support. The use of simulation models at the corporate or industry level would typically be considered strategic decision support while simulation at the product/process level would be operational support. Simulation
at the plant level could indicate tactical support. However, it might also be either strategic or operational support. At the industry level more than 50% of the respondents did not use simulation, whereas at the product/process level almost 80% indicated some use of simulation. Comparisons of mean scale scores in the study and those in the earlier study (23,63) show little difference in the scores at the corporate, plant, and industry levels. At the production/process level, there was an increase in usage based on the mean scale score. This result is not surprising since, at this level, the problem and environment are relatively structured and straightforward and therefore lend themselves to simulation modeling. At this level the data required for simulation is more readily available (routing, inventory etc.) than data needed at other levels. This has been increasingly true over the last ten years as many operational level manufacturing control systems have been implemented. In addition, it is at the product/process level that many specialized simulation language have been developed and implemented (for example GERT, SLAM, GEMS and others).

Managers were asked to indicate the use of simulation in the functional areas of business. The production function makes the most frequent use of simulation as reflected by the high mean scale score
(3.59) and the high percentage of managers (35.1) indicating very frequent use. In contrast, about 20% of the respondents never use simulation in the finance and marketing areas. The order of the functional areas according to mean scale scores has not changed from the earlier study. However, an increase in the degree of use of simulation is indicated in the area of finance. In production this can be explained, at least in part, to the structure associated with the manufacturing area resulting from the increased understanding of that area that has occurred as a result of study and experimentation over the last ten years. The increased availability of good data and of highly functional simulation languages is also a factor. The increasing implementation of MRP II systems, and the associated interest in simulating those systems, may also explain the increase as well.

Table 1.2 below depicts the summary of responses to questionnaire.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Mailing</th>
<th>First</th>
<th>%</th>
<th>Second</th>
<th>%</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Number of responses</td>
<td>Percentage of responses</td>
<td>Number of responses</td>
<td>Percentage of responses</td>
<td>Number of responses</td>
<td>Percentage of responses</td>
</tr>
<tr>
<td>A</td>
<td>18</td>
<td>7.2</td>
<td>22</td>
<td>8.8</td>
<td>40</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>4.8</td>
<td>20</td>
<td>8.0</td>
<td>32</td>
<td>12.8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>6.0</td>
<td>42</td>
<td>8.4</td>
<td>72</td>
<td>14.4</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.2: Summary of responses to Questionnaire

Source: (20)
Simulation modeling is used at all levels of management in the 500 largest corporations in the United States. The data in this study (1985) (20) and the earlier study (23,65) indicate the most frequent use is at the product/process level.

Within the functional areas of business, simulation modeling is most heavily used in the production area. Applications in scheduling and inventory analysis/ control are most common, but frequent application to other production areas was also reported. In addition, finance and marketing showed fairly high use of simulation. In finance the dominant application was capital budgeting and in marketing both contract building and sales analysis, simulation was seldom used in the personnel area.

Results of the study, taken as a whole, do not seem to indicate much increase in the overall use of simulation modeling since 1975. This is somewhat surprising considering the continuing emphasis on quantitative analysis in business and engineering schools at both undergraduate and graduate levels and the increased availability of micro computers and specialized simulation software. In addition to those discussed previously in each area, two possible reasons for this can be gleaned from the comments of some respondents. First, simulation is too sophisticated and time consuming to use in making quick decisions in a dynamic environment. Second and
more plausible is the application of operations research/management science (OR/MS) techniques in general have been integrated into the functional areas of the organization, representing a decentralization of this function. (The OR/MS function or department is less frequently a stand-alone unit; rather users are scattered through the organization). This being the case, it is possible the results here may underestimate the actual use of simulation through the organization. (This also helps explain the lower response rate in this study as compared to 1975 study).

Further attempts to determine the use of simulation modeling in large organizations may require a different approach. Based on the second reason, research is first needed to investigate the current status of the organization of the OR/MS function to determine organizational changes that have occurred over the past ten years. Results of such an investigation may help to identify an improved approach for gathering data and answering questions concerning the utilization of simulation within large corporations.
SECTION - IV

SURVEY OF FORECASTING
The forecasting of future sales of products and the usage of components is very important in production planning and control. Good forecasting is essential to efficient production operations. Forecasting is sometimes done by a "top down" method. In other cases, the reverse "bottom up" method, is used. And in still other cases, past experience is projected forward and extrapolated into the future by using mathematical procedures.

Sometimes Simulation Analysis is also used to forecast future sales demand. Obviously the future sales demand is projected forward based on past historical data, whether the forecasting is done by past experience projected forward and extrapolated into the future by using mathematical procedures or by simulation analysis using probability distribution of demand data of past. The future demand data is generally not as accurate as one wish to have; but however it does give the management of business organisation and research workers some insight into the future trend of the demand of products and components, in which they are interested for future planning or prediction for research purposes.

Various research workers have been working on forecasting techniques in the past. Before 1960, little empirical research was done on forecasting methods, since then, the literature has grown rapidly, especially in the area of judgement forecasting. Armostrong, J. Scott (69)
supports and adds to the forecasting guide lines proposed before 1960, such as the value of combining forecasts. New findings have led to significant gains in our ability to forecast and to help people to use forecasts.

A set of computer simulation 1980 (16) were designed to investigate the use of winters forecasting models with the adoptive system of Trigg and Teach for short term forecasting (16). These two methods are popular and effective methods used for short term forecasting, but no systematic study of their joint usage has been reported. The result provide a set of smoothing constant limits which yielded accurate forecast for experimental conditions investigated. The experimental conditions were designed to cover as wide a situations as possible to maximum potential usefulness to practitioners.

Sometimes sporadic or lumpy demand pattern is characterized by large transactions separated by periods of zero demand. Such demand patterns occur frequently for items in parts and supplies inventory system. Schults 1987 (68) presented forecasting procedure to be used in conjunction with a base stock order up to inventory control policy under periodic review. The procedure determines the size and timings of replenishment orders. Although a base-stock policy calls for a replenishment order after each transaction, it is shown that a delay in
placing the order can result in significant holding-cost reduction with little additional risk or cost of stock outs.

Benito and Clay 1986 (19) report on the performance of two forecasting systems, one recommended by practitioners for use in inventory management, and the other, the result of an international forecasting competition among academics. The practitioner-developed approach chooses one forecast from a collection produced by simple forecasting models for purpose of making the next period's forecast. The academic approach on the other hand, advocates using the average from all the models for the next period's forecast. The performance of the two approaches is compared with that of simple exponential smoothing model for both empirical and synthetic time series data.

Over the last several years, a significant debate concerning the values of forecasting and the quality of different techniques has taken place. A part of the argument is focused on the philosophical issue of whether it is more important to improve forecast or to improve our ability to live with poor forecasts. A practical answer to this debate seems to be unequivocal "Yes" - both areas are important.

Short-term demand forecasts are needed for inventory control, labour questions (e.g. overtime,
temporary employment, and layoffs), and for many purchasing decisions. Techniques like exponential smoothing have received wide recognition and use, and this attention has prompted the development of more techniques and an interest in comparing them. The near coincidence of two such events stirred the desire of Benito and Clay in performing the comparison reported in their article. The first event was the publicity received, and the practitioner interest in the focus forecasting system developed by Bernard Smith of the American Hardware Supply Company (73). The second one was an international forecasting competition among academics (19).

The focus forecasting methodology has come out of industry as a simple but effective technique (73). It is based on observations of how people actually forecast demand and tries to capture their ideas. It is not an expert system, although it is built on empirical observations and the insights of persons making forecasts.

The approach of most academics to the forecasting problem is that of developing theoretical models which capture underlying demand patterns. The models are based on information about such demand attributes as seasonality and/or trend. The international competition provided a basis for comparing many of these approaches. The forecasting systems that are evaluated here reflect some of the differences between the empirically based and theoretically based approaches.
The results differ between the synthetic and the empirical data. On the synthetic time series, the performance of the all three techniques were highly significant. The simple exponential smoothing model could not cope with the trend and seasonal components present in some of the time series, and its performance is the worst on both criteria.

However, the story is quite different on the empirical data, the magnitude of the error measures, MAD, MAPE, increased over the results for the synthetic series. This indicates that the empirical time series are far more difficult to forecast than the synthetic. It also makes it more difficult to discriminate among techniques. The exponential smoothing model does outperform the other two.

The pragmatic implications of the experiment are also clear. Forecasting actual demand is difficult. Unfortunately, the results do not provide a consistently superior choice of forecasting technique, but do tend to support the conclusions from the international forecasting competition that simple forecasting models are useful. They do not support the use of the averaging approach for the empirical time series.

However, the message to researchers rings clear: be careful in drawing "real world" conclusions from laboratory data.
Rochilley Cohen and Fraser Dunford 1986 (14) forecasted demand for telephones of the Manitoba Telephone System (MTS), in order to control the inventory in their phone centres. Although this appears to be a very straightforward problem, data difficulties made it impossible to use most of the common forecasting models. Nevertheless, the use of a very simple forecasting model resulted in an inventory reduction of 45 percent.

The main objective of future forecasting in planning and control of business organisation is to know in advance the requirement of parts and sub-assemblies in order to reduce work-in-process inventory which in turn reduce the overall cost of products which further result in higher profits: the primary aim of all business organisations.

To have good forecast is in the interest of business organisations, considerable research has been done in the recent past for improving the efficacy of forecasts of demands both by practitioners and academicians. Still the results obtained are not so encouraging as it should be.