JUST IN TIME MANUFACTURING: A MIGRATION FROM MATERIALS REQUIREMENTS PLANNING

THESIS

Scott A. Koehler, B.S.
Captain, USAF

AFIT/GCA/LAS/95S-5

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Scott A. Koehler, B.S.

Captain, USAF

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Scott A. Koehler

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Abstract

Manufacturing planning and control systems play an important role in an organization's effectiveness. Over the past twenty to thirty years, U.S. manufacturing companies have faced increasing competition for market share from Japanese and other Pacific rim countries. This thesis will investigate the evolutionary path followed by manufacturing companies that have implemented various manufacturing planning and control systems. Specifically, Materials Requirements Planning (MRP) and Just In Time (JIT) production will be analyzed. MRP is a means of converting demand for the final product into a requirements schedule for the various components comprising that product. The JIT philosophy calls for continuously improving all parts of the manufacturing function, such as, plant layout and design, organizational structures, total quality management, and vendor relationships. Why is this an area of interest to American manufacturers? MRP is an American development, and many American manufacturers have implemented MRP systems since the late 1950's. However, recent emphasis on time-based competition within manufacturing organizations has caused many of those companies to supplement their MRP systems with a JIT system. In other words, a JIT system has supplanted the MRP system. MRP and JIT are not competing approaches to planning and controlling manufacturing operations; each offers benefits not offered by the other alone. This fact suggests that the most ideal manufacturing planning and control system will probably embody elements of both MRP and JIT.

JUST IN TIME MANUFACTURING: A MIGRATION FROM MATERIALS REQUIREMENTS PLANNING

I. Introduction

Chapter Overview

Manufacturing planning and control systems play an important role in an organization's effectiveness. Over the past twenty to thirty years, U.S. manufacturing companies have faced increasing competition for market share from Japanese and other Pacific rim countries. As this competition has increased in intensity, a variety of techniques, philosophies, or quick fixes have been tested. This thesis will investigate the evolutionary path followed by manufacturing companies that have implemented various manufacturing planning and control systems. Specifically, Materials Requirements Planning (MRP) and Just In Time (JIT) production will be analyzed. This chapter justifies the analysis by presenting the general issues surrounding MRP and JIT concepts. The chapter then provides a detailed problem statement with the appropriate rationale for conducting research in this area. The resulting research objectives and brief background review follow. Finally, a summary of the methodology employed with a description of its scope and limitations is provided.

General Issue

Manufacturing organizations have implemented planning and control systems such as MRP and JIT manufacturing in an attempt to increase plant productivity (Cheng and Podolsky, 1993: 1-7). MRP is a means of converting demand for the final product into a requirements schedule for the various components comprising that product (Nahmias, 1993: 303-305). Using this requirements schedule, a complete production plan is determined for a given planning horizon. A JIT manufacturing system consists of more than just a logical method of generating a production schedule. The JIT philosophy calls for continuously improving all parts of the manufacturing function, such as, plant layout and design, organizational structures, total quality management, and vendor relationships (Nahmias, 1993: 345-346). Lockamy and Cox identify the underlying goals of JIT manufacturing thusly: to allow an organization to be more flexible, to make more effective use of productive resources, to improve key business results, and to simplify the business (Lockamy and Cox, 1991: 1661).

Why is this an area of interest to American manufacturers? MRP is an American development, and many American manufacturers have implemented MRP systems since the late 1950's. However, recent emphasis on time-based competition within manufacturing organizations has caused many of those companies to supplement their MRP systems with a JIT system (Harrison, 1992: 13-19). In other instances, a JIT system has supplanted the MRP system. It is important to note that MRP and JIT are not competing approaches to planning and controlling manufacturing operations; each offers benefits not offered by the other alone. This fact suggests that the most ideal manufacturing planning and control system will probably embody elements of both MRP and JIT.

As has already been stated, the trend toward integrating the two approaches has already begun, but in the opinion of this researcher, it has not progressed nearly far enough, especially within the Department of Defense (DoD) industrial manufacturing base. The defense budget is shrinking rapidly, but the national security of the United States remains an important concern. Therefore, the DoD industrial manufacturing base will continue to be called upon to produce the weapon and support systems required for national security. It is vitally important that the companies which compose the DoD industrial base adopt processes that will enable them to continue to supply the DoD's needs. This researcher thinks that if it can be shown that a planning and control system embodying the elements of both JIT and MRP is the most cost effective method for controlling manufacturing operations, knowledge of this fact should be widely disseminated among all the DoD contractors. Implementing such a system could potentially help offset the loss of DoD purchasing power due to a declining DoD budget.

Problem Statement

> **Many American companies have implemented MRP planning and control systems with high expectations for improved productivity and profitability. Yet, a few years later those same companies have found themselves busily engaged in implementing a JIT based planning and control system still in search of improved productivity and profitability.**

This statement guides the thesis. This research constitutes the first stage of a two-stage effort. It seeks to find the major factors that cause a manufacturing firm to migrate from an MRP planning and control system to a JIT system, still far short of its productivity goals. Identifying weaknesses in an MRP system that drives manufacturers to implement a JIT system will enable DoD procurement managers to better evaluate a potential contractor's manufacturing planning and control system to identify potential problems in economically producing a system after it has been developed and tested. Specifically, analyzing the experiences of current and past contractors that have successfully implemented JIT system after having implemented an MRP system will provide historical information currently unavailable. This information will be useful in developing an acquisition strategy aimed at encouraging contractors to install a planning and control system best suited to controlling their manufacturing operations. Where deemed appropriate, contract incentives could be used to encourage contractors to install the planning and control system most appropriate for their operations.

The entire two-stage research effort will test the validity of the following hypotheses (H1 through H5).

H1. Manufacturing organizations are motivated to implement an MRP planning and control systems to solve operational problems that are unmanageable using a order point planning and control system.

H2. Organizations operating under an MRP planning and control system are motivated to implement a JIT system to solve operational problems that have been found to be unmanageable by an MRP system.

H3. A combination MRP/JIT planning and control system will eliminate most of the operational problems that have proved to be unmanageable by either MRP or JIT alone.

H4. The improvements gained from implementing an MRP planning and control system flow primarily from improved information about a company's existing operating environment and are limited by that environment.

H5. The improvements gained from implementing a planning and control system which combines the JIT philosophy with MRP techniques flow primarily from changes in the physical operating environment.

The last two hypotheses reflect the researcher's belief that MRP is merely a transitional stage on the path of evolution from an order point planning and control system to implementation of the JIT philosophy, augmented as circumstances require by appropriate

MRP techniques. The researcher postulates that a company operating under an order point planning and control system can achieve significant improvement merely by gaining better information about its current environment. However, the physical and technological environment within which order point and MRP control systems thrive are not well suited for successful competition in world wide markets. Such competition demands the discipline and efficiency of a JIT operating environment, which can be achieved only by restructuring the MRP operating environment. Tests of the last two hypotheses will require in depth interviews with company personnel, and therefore will not be accomplished as part of the current effort.

Research Objectives / Questions

R1. Are specific industries more likely to implement JIT concepts than are others?
R2. What are the customer base, manufacturing type, and production volume characteristics of companies that use both MRP and JIT?
R3. Why have manufacturing firms implemented MRP and JIT?
R4. How complete was the installation of MRP when JIT concepts were introduced?
R5. What problems have been improved through the simultaneous use of MRP and JIT systems? What problems still exist?

These five questions help further define the focus of this first stage research effort.

Background

Toyota Motor Company is credited with the first large-scale application of JIT in the late 1960's and early 1970's (Suzaki, 1987: 25-34). In this case, JIT described a system where raw materials arrive at the plant "just in time" to meet demand. As a production planning and control system, JIT has expanded its definition to include quality improvements, lower capital investment in inventories, shorter lead times, and on-time deliveries (Manoochehri, 1988: 23).

Existing literature reveals specific benefits from JIT implementation. The examples below uncover some representative results of manufacturing organizations that have implemented JIT.

> 1. Kawasaki Motors in Lincoln, Nebraska implemented a JIT parts delivery system in the 1980s. An effective operation is facilitated by a smaller number of nearby suppliers. A key supplier to Kawasaki reportedly makes two deliveries per day. More distant suppliers make deliveries every three days. Kawasaki's greatest benefit is a reduction in inventory investment and the related carrying costs. In addition, Kawasaki notes that paperwork is reduced, lead times are cut, and more time is available for projects as a result of fewer quality and delivery problems. (Giunipero and Keiser, 1988: 20)
>
> 2. Burndy Corporation, an electronic connector manufacturer, began implementation of JIT concepts in 1988. Several positive results have been reported to include: 1) production lot time was reduced from over one week to 1.5 hours, 2) the scrap rate was lowered from in excess of 20% to a rate of under 2%, 3) late shipments valued at $300,000 were eliminated, and 4) over 5000 square feet of production floor space was eliminated. (Jonas, 1991: 39)
>
> 3. Wilson Sporting Goods, Humboldt, Tennessee, produces a variety of sporting equipment to include golf balls. JIT was introduced in the Humboldt plant in 1985 with remarkable results to follow. The plant manager estimates plant savings to be near $13 million just throughout 1989 alone. Inventory turnover has increased from six to sixty. Quality costs were lowered by over 60% while rework dropped by 80%. Overall job satisfaction improved due to participative management and employee involvement. (Scott, Macomber, and Ettkin, 1992: 37-38)

The three studies above were in-depth case studies purely addressing JIT concepts. An interesting preview to the chapters to come is the fact that Kawasaki Motors once utilized a MRP planning and control system. Kawasaki Motors is not alone in the application of JIT following a MRP system. There are many more companies out there that have done the same thing, and this study will provide more insight into these specific companies. In the literature reviewed to date, there is an approximate 60 / 40 split between case studies and surveys, respectively. A pitfall of both types of data gathering techniques is generalizing the results over an entire population. Even when survey controls are in place, other external factors (inflation, interest rates, wartime environment, etc) could cause some of the reported benefits to either increase or decrease in magnitude.

The JIT system of business management can work in firms of all sizes and types (Tucker and Davis, 1993: 60). If the DoD promotes JIT implementation within the industrial manufacturing base, benefits such as the ones mentioned above could be realized. For this study to be a success, the motives of companies like Burndy and Wilson to switch to JIT must be revealed. A major area of concern in the literature review is the time involved in implementing JIT. As the literature reveals, JIT does not result in overnight success stories. It takes time to implement JIT, as well as time to reap the benefits of the new system. How does this problem influence the study? As the literature revealed, JIT can be implemented in many different ways (Sage, 1987: 84). There must be a realization that the answers received to the problem statement and research objectives will vary according to the stage of JIT implementation. A firm that is just starting JIT implementation may be very discouraged at the slow pace of change. At the same time, a firm that has had JIT in place for some time may overreact to its benefits. To combat this potential problem, analysis will be conducted on firms in varying degrees of JIT implementation and comparisons made of their reported benefits. From firms in varying stages of JIT, identification will be made of the root causes of change to JIT and the current stage of implementation.

Some general conclusions can be made in regard to this literature review. JIT can produce valuable results to the DoD. A noted benefit is the reduction in lead times to the ultimate customer--either the DoD or a prime DoD contractor. Secondly, JIT can increase on-time deliveries of weapon systems thus avoiding cost and schedule overruns. Finally, JIT can increase contractor efficiency. With increased efficiency, the DoD will be able to offset the decreased fiscal budgets. Hopefully, program managers will be able to buy weapon systems at a lower unit cost.

Methodology

A questionnaire will be sent to manufacturing organizations that have implemented an MRP system and also have adopted some JIT concepts. The questionnaire has six distinct sections. Section I solicits the specific type of industry, the manufacturing type, and the production volume. Section II solicits the respondent's job title and experience with JIT. MRP is the focus of section III. Specifically, section III asks why MRP was implemented and explores the types of problems being experienced with the system. Section IV focuses on the length of time MRP was in place when the company decided to implement JIT. The "whys" behind the migration to JIT is the focus of section V. And finally, section VI asks specific questions about the success of integrating the JIT philosophy. These section descriptions, though not comprehensive, are representative of the general theme. A detailed methodology is included in chapter 3.

To be concise, this research effort is restricted in several ways. The limited research study includes only United States manufacturing firms that have transitioned from MRP to JIT (or at least have had MRP in place). This will eliminate firms that started business with JIT in place. The study is also restricted in the number of "reasons" why firms have transitioned to JIT. It would be nearly impossible to identify every reason conclusively, so the study will focus primarily on thirteen identified reasons found in the current literature to date on JIT. As mentioned earlier, time-based competition is a distinguishing characteristic among successful manufacturing firms. For the DoD, time-based manufacturing equates to reduced lead times in the fabrication and assembly of weapon systems. As a result of reduced lead times, manufacturing costs should decrease.

The research problem will not be confined to only large manufactures (500 + employees). More than half of all the dollars expended for defense material go to smaller manufacturers via subcontracting (DSMC, 1989: 32-50). In order to get a representative sample of the JIT users, the study will look at both large and small manufactures in repetitive, batch, and project type organizations.

Summary

This chapter established the focus of this research effort. In responding to the problem statement and research objectives, this study will yield both general conclusions and recommendations. The study will not provide a mathematical model informing manufacturing managers when to implement JIT. Statistically, the survey will reveal the hypothesis testing, frequency, and types of characteristics that led firms to implement JIT from a MRP system. Large and small manufacturers will be able to compare their current production processes in terms of customer base, manufacturing type, and production volume to see if they are currently experiencing similar problems with their planning and control system. The transition process undertaken by the surveyed firms will reveal the length of time involved to fully transition to JIT. Reporting the transition process to be either a natural progression involving the entire firm or potentially involving only certain divisions of firms will be made.

II. Literature Review

Chapter Overview

As the title of this thesis implies, there has been a migration or progression from MRP to JIT planning and control systems. To the extent that this progression has occurred, it is important to provide a brief historical perspective of the Operations Management (OM) field. Within this historical perspective, major concepts and contributions will be identified that have helped to define the OM field of study. Next, MRP and JIT planning and control systems will be reviewed separately. It is important to understand the complexity of both concepts before directing attention to the combination of MRP and JIT. Finally, the notion of combining MRP and JIT systems will be investigated.

History of Operations Management

It could be argued that operations management has existed for hundreds of years, since the production of goods and services has been going on that long. However, the field of scientific management, which has become a historical benchmark for the OM field, was established by Frederick Taylor in 1911 (Taylor, 1911: 36-37). Scientific management established many techniques in current use, such as time and motion studies, work simplification, and standard methods. Taylor, an engineer, developed four principles of scientific management, to include: 1) develop a science for each element of work, 2) scientifically select and then train, teach, and develop the worker, 3) management should ensure the job is completed within the guides of scientific management, and 4) it is the responsibility of the worker to carry out the wishes of management without question. Underlying the scientific management principle is the specialization of labor or classifying a job so that it is extremely "routine" by nature. Some recognizable researchers that worked with Taylor include Frank and Lillian Gilbreth (motion studies, industrial psychology) and Henry Gantt (scheduling, wage payment plans).

Coupled with the principle of scientific management, Henry Ford established the moving assembly line in 1913. Ford automobiles were then assembled via a continuous moving assembly line that reduced labor time per chasis from 12.5 hours to 93 minutes. In 1917, F. W. Harris introduced the economic lot size model for inventory control. This model was later used by large manufacturers such as Ford Motor Company in an attempt to reduce inventories. Walter Shewhart, H. F. Dodge, and H. G. Romig introduced early concepts of statistical quality control. In 1931, Shewart, Dodge, and Romig presented sampling inspections and statistical tables used in quality control measures.

Elton Mayo, a sociologist, carried out the Hawthorne studies during the early 1930s. The studies were conducted in the Western Electric plant in Hawthorne, Illinois to determine the effects of environmental changes on worker output. Up to this point in OM history, studies were based primarily on mathematical and statistical theory. Now Mayo introduced the human aspect of OM and found interesting results. Mayo concluded that workers were motivated by more than just pay. The task-oriented approach employed by the scientific management community treated workers as pawns in the productive environment. Mayo's findings motivated organizations to implement human relations and personnel management departments in an attempt to capture the positive contributions the individual worker could bring to the job.

Operations Research (OR) was developed during the 1940s when World War II created the need for effective weapon designs. OR combines the diverse fields of economics, mathematics, and psychology in an attempt to quantify solutions to complex problems. OR utilizes methods such as simplex linear programming developed in 1947 by George Dantzig. Many other tools were soon to follow in the 1950s when OM began to emerge as a distinct field of study.

OM blossomed as a field of study in the 1950s and early 1960s with the introduction of concepts such as simulation, waiting line theory, decision theory, mathematical programming, computer hardware and software applications, and project scheduling techniques such as PERT and CPM. With these useful tools, the emphasis was on the entire productive system within an organization. Management now realized that producing an end product occurred within a system and managing the operations was a key ingredient to a successful business.

The 1970s saw the introduction of computers to the OM field. For the first time, computers provided managers with a rapid response tool to changing production schedules and internal demand for component parts. MRP was introduced as a computerized information system which allowed managers to manipulate thousands of items or parts. MRP was a major break through which provided real-time answers to complex production scenarios. In addition to MRP, software packages were developed to model facility layout, inventory, scheduling, and forecasting.

During the decade of the 1980s and continuing today, many firms realized the importance of manufacturing as a competitive tool. Concepts such as JIT, total quality control (TQC), and factory automation have become common place. Important leaders in this area include Tai-ichi Ohno (Toyota Motors, Japan), Edward Deming (quality concepts), and Joseph Juran (quality). Factory automation such as computer-integrated manufacturing (CIM), flexible manufacturing systems (FMS), computer aided design and manufacturing (CAD/CAM), and factory of the future (FOF) are usually an integral part of manufacturing strategies today.

For the 1990s and beyond, the pursuit of quality will be prevalent. Total quality management (TQM) awards and certifications such as the Baldrige National Quality Award and ISO 9000 will be widespread. The Baldrige award recognizes up to five companies a year for their outstanding quality accomplishments. ISO 9000 certification helps set quality standards for international manufacturers and is often a prerequisite for manufacturing companies in order to receive contracts. Finally, business process reengineering (BPR) has been advocated by Michael Hammer and others. BPR challenges businesses to take a revolutionary look at processes and procedures which are a waste of company resources. BPR has taken hold in manufacturing industries due to increased global competition and the need to become lean manufacturers.

This historical perspective of the OM field has covered nearly the entire 20th century from 1911 to present. As the above shows, there has been an evolutionary change in the way we view OM and in the concepts that were introduced. MRP and JIT are two relatively young concepts as compared to others introduced above. As such, the way these concepts are viewed probably will change with time. As new adaptations for MRP and JIT are introduced, the definitions of both may broaden. For now, both concepts provide a vast array of information. The following sections will describe both MRP and JIT in more detail.

Materials Requirements Planning

MRP is a computer-based production planning and inventory control system. MRP can be described as a "time phased requirements planning" schedule concerned with both production scheduling and inventory control. Scheduling, material control, and rescheduling due to revised production plans are provided with the MRP system. The system attempts to keep inventories low as well as assuring that component materials are available when needed. The following flow diagram, figure 2.1, shows how a typical MRP system may function.

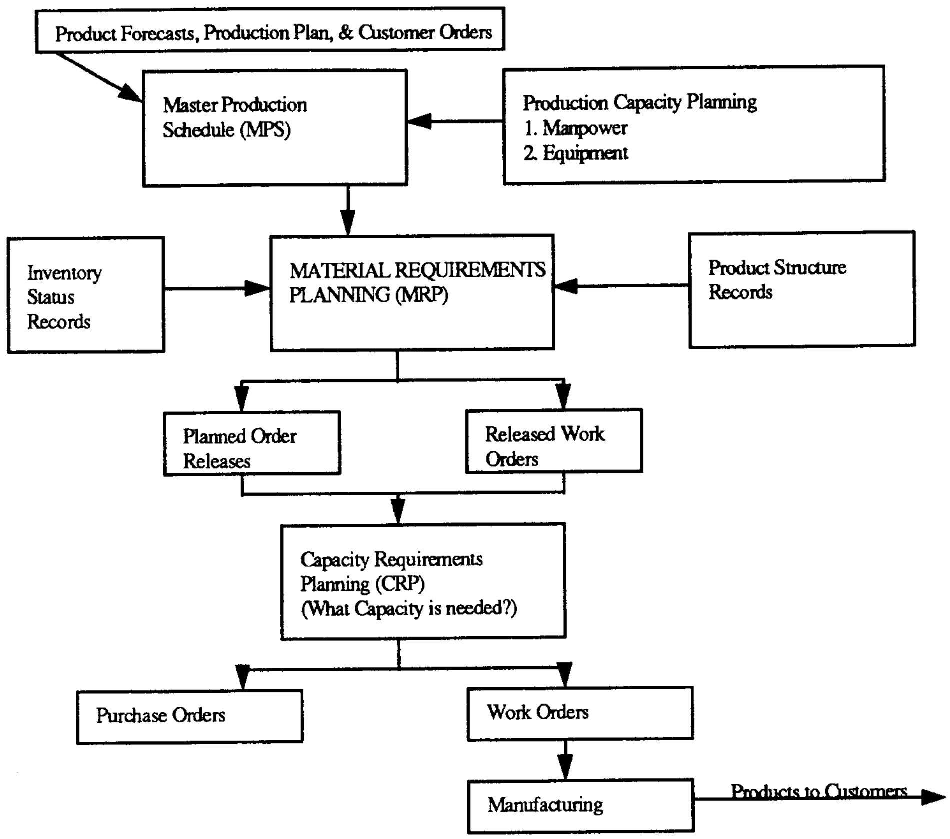

FIGURE 2.1 MRP System

MRP systems have often been characterized as "push" systems of production. Work in process (WIP) is pushed to the next level (department) as soon as the work for that department is completed. As figure 2.1 indicates, MRP receives inputs from three areas to include: the master production schedule (MPS), inventory status record, and product structure records. The MPS incorporates demand forecasting and customer orders to answer the questions, "What end-products should we produce?" and "When are they needed?" The MPS takes into account production lead times and often incorporates several one-week planning increments. With regard to production capacity, the MPS must be realistic as opposed to a forecast which often exceeds the plant capacity. The MPS, with its leveled production plan, is the driving force behind MRP. MRP translates the end-item external demand into internally driven material requirements for components and raw materials which make up the end-item.

The inventory status record is an up-to-date journal of all items in the inventory. This account would include any items currently on-hand and items which have been ordered. The MRP system uses the inventory status record to ensure overall requirements take into consideration what is already available in terms of raw materials or purchased parts.

The product structure records is another name for the bill of materials (BOM). The BOM is a detailed listing of every item or assembly required to produce an end-item. For planning production, the BOM will provide a detailed listing of part numbers, part descriptions and quantities, and assembly/subassembly descriptions for the end-item in question.

The primary outputs of the MRP system are the purchase orders and work orders. To derive the quantities for these orders, MRP "explodes" the end-item product structure into the lower level components. Exploding the requirements simply means multiplying the end-item requirement (quantity) times the quantity of each component used to produce the end-item. Once this process is complete, the planned order release is derived by the MRP system. The planned order release ensures that lead times are considered for components that have to be procured from outside companies (subcontractors) as well as items and raw material requirements for in-house production.

The MRP system described above established a method for ordering inventory, scheduling, and establishing valid due dates on orders. In the 1980s, MRP broadened its focus to include functional areas such as manufacturing, marketing, engineering, accounting, and finance. The result of this broadening effort brought about the concept of

Manufacturing Resource Planning (MRPII). MRP is now a subset within MRPII. MRPII serves as a focused planning and control system which incorporates the strategic goals of an organization into the production plan. Figure 2.2 below represents a typical MRPII system.

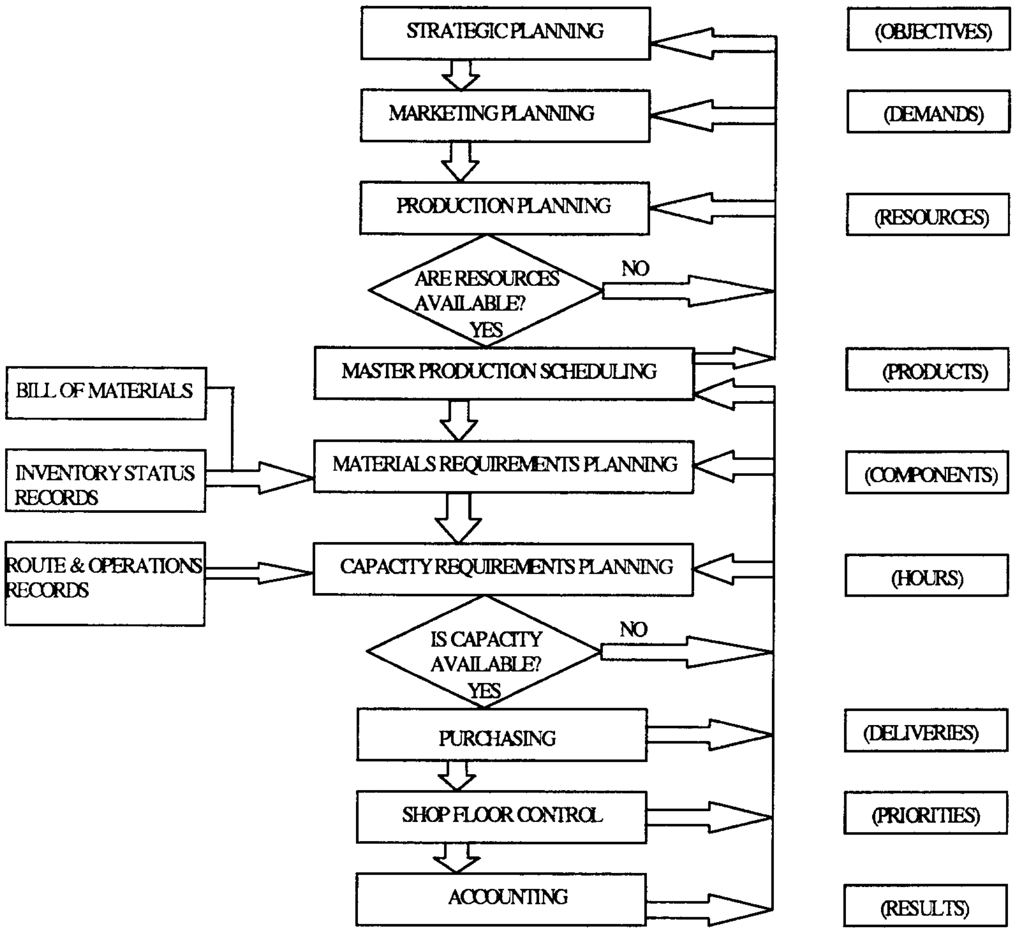

FIGURE 2.2 MRPII System

As you can see from the above figure, MRPII takes a macro perspective of the manufacturing process. MRPII includes planning and control activities from various functional areas within a company. Strategic planning addresses the company objectives. Marketing planning identifies the demand for the product in question. Taken together, strategic and marketing planning represent an overall business plan for the organization (Wallace, 1990: 254). Usually, the business plan would be the responsibility of the general manager. The business plan takes into account the marketplace (customer orders and forecasts), the capabilities within the company (people, skills, available resources, technology), financial targets (profit, cash flow, and growth), and strategic goals (levels of customer service, quality improvements, cost reductions, productivity improvements, etc.). MRPII can be viewed as an extension of MRP. MRP is a valuable tool within MRPII. With increased emphasis on the systems approach to production, MRPII provides the system integration that may have been lacking with MRP.

Production planning in MRPII identifies the resources needed to produce an end-item. The primary purpose of production planning is to execute the business plan. Planning will be accomplished for all end-items which are produced in an attempt to develop an aggregate production plan. Again as was seen in MRP, the MPS identifies the products that should be produced. To understand the different perspectives taken by MRP as compared to MRPII, consider the purpose of the MPS. In the MRP system shown in figure 2.1, the MPS would be considered an input only feeding into the MRP function. For an MRPII system such as the one shown in figure 2.2, the MPS would be considered an integral part of the system or as a decision variable. The difference is key. For MRPII, all of the functions shown above in figure 2.2 are considered important decision variables. To vary one of these functional areas would impact others; therefore, MRPII works as an overall system. Functional areas work together to carry out the business plan. Once MRP is completed, the hours or capacity required to fulfill the production plan are determined. This function is called capacity requirements planning (CRP). A determination must be made as to whether or not the plant has the capacity to produce. Most all manufacturers are not self sufficient. Purchasing from outside vendors is required for various subcomponents and raw materials. Purchasing must be concerned with the timing of deliveries. Deliveries must take into account production lead times and the "need" date for the production process.

The production floor is a very busy place where several different end-items are being produced at the same time. To keep the sequence of processing jobs straight, shop floor control (SFC) is utilized. SFC prioritizes the work. Often, end-items require a specific sequence for fabrication and assembly. SFC prioritizes the sequence to make sure the end-item meets the delivery date. The final part of the MRPII system is the accounting function. The accounting function analyzes the results of operations to see if the long range business plans are being met by the detailed efforts of the production process. The accounting function can provide insight into problems which may hinder the accomplishment of the business plan.

Where can MRPII be used? MRPII can be used in any industry type to include: assemble-to-stock, fabricate-to-stock, assemble-to-order, fabricate-to-order, manufacture-to-order, and process (Chase and Aquilano, 1995: 589-590). Table 1 below identifies some industry applications and benefits from installing MRPII systems.

TABLE 1

Industry Applications and Expected Benefits of MRP

INDUSTRY TYPE	EXAMPLES	EXPECTED BENEFITS
Assemble-to-stock	Combines multiple component parts into a finished product which is then stocked in inventory to satisfy customer demand. Examples: watches, tools, appliances.	High
Fabricate-to-stock	Items are manufactured by machine rather than assembled from parts. These are standard stock items carried in anticipation of customer demand. Examples: piston rings, electrical switches.	Low
Assemble-to-order	A final assembly is made from standard options that the customer chooses. Examples: trucks, generators, motors.	High
Fabricate-to-order	Items manufactured by machine to customer order. Generally, industrial orders. Examples: bearings, gears, fasteners.	Low
Manufacture-to-order	Items fabricated or assembled completely to customer specification. Examples: turbine generators, heavy machine tools.	High
Process	Industries such as foundries, rubber and plastics, specialty paper, chemicals, paint, drugs.	Medium

Even though MRPII can be installed in any industry type, the above table shows that benefits are low for industries where machine fabrication takes place. In areas where assembly is required, MRPII is effective and provides many benefits. For the DoD, most weapon systems would fall in the manufacture-to-order category where benefits from MRPII are high. An interesting point is that MRPII is most effective when the production quantities are relatively high. What are the implications for the DoD? It appears that even though a few major weapon system acquisitions are still around (i.e.: C-17, F-22), the production quantities per year may be fairly low due to shrinking DoD budgets. Another consideration is the push within the DoD to procure off-the-shelf non-developmental items. Obviously, this is not an option for all DoD procurements; however, the push is on to buy common commercially applied items. This endeavor would fall into the assemble-to-stock category above. Again, the DoD could benefit because the benefits are high for MRPII systems in this type of industry.

A study was completed by David Turbide in which he surveyed various industries to see if they used MRPII systems (Turbide, 1993: 12). The results are shown below in figure 2.3.

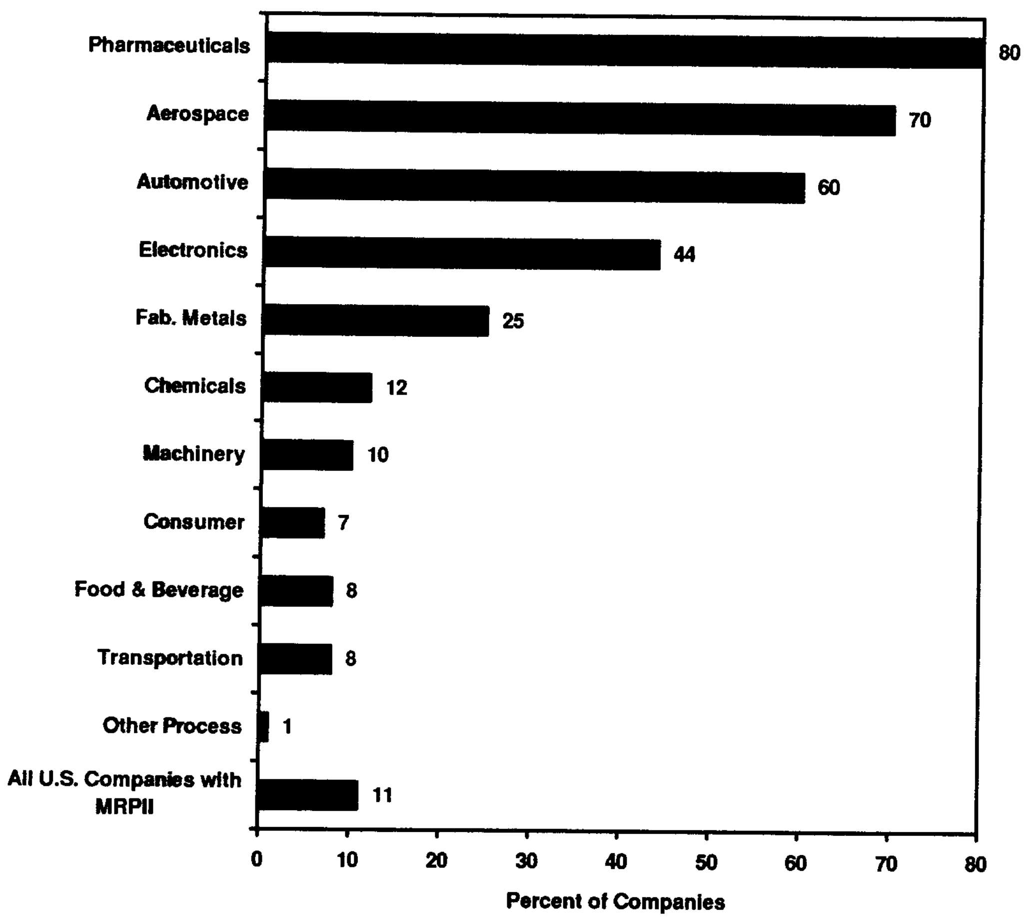

FIGURE 2.3 U.S. MRP Use By Industry

An interesting point is that only 11% of all U.S. manufacturing firms have some type of MRPII system according to Turbide. He completed his survey in 1993. At that time he estimated that nearly 65,000 U.S. firms had an MRPII system installed out of a total of nearly 550,000 manufacturing firms. This leaves much room for future growth. For purposes of this study, it is important to note that 70% of the aerospace companies have an MRPII system in place. With expected benefits high from manufacture-to-order type industries, it is likely that more aerospace companies will implement some type of MRPII system.

Another survey of 14 aerospace and defense (A&D) contractors supports the above findings that MRPII is used within the A&D industry (Kaylor, 1993: 658). Kaylor asked the surveyed companies to respond on their current MRPII usage characteristics. The MRPII usage characteristics are as follows: 1) Class A -- the system is used by all areas/functions to manage the business, achieving outstanding results, 2) Class B -- the system is used by manufacturing and materiel to schedule and load, producing very good results, 3) Class C -- the system is used for ordering with fair to good results, and 4) Class D -- the system only works in data processing. Of the 14 responses to the survey, Kaylor received two class A responses, seven class B, three class C, one class D, and one was not ready to be rated. Some additional findings of Kaylor are shown in table 2 below.

TABLE 2

MRPII Potential Improvements

MEASURE	BEST IMPROVEMENT	AVERAGE IMPROVEMENT
Inventory turnover up by	92%	47%
Work in process down by	75%	45%
Expeditors reduced by	75%	35%
Purchased commitments down by	35%	28%
Overtime down by	50%	30%

The above table gives some idea of the improvements that can be made with an MRPII system. The wide spread from this survey is probably due to various degrees of implementation of the MRPII systems within the 14 contractors surveyed. With companies like these continually implementing various stages of MRPII, improvements will continue.

Just like any other input a manager might evaluate to make a decision, so too is MRPII an input to decision making. MRPII does not make decisions for the manager, but it helps support and facilitate the decision making process. The benefits derived from an MRPII system are prevalent across all organizational functions. For the organizational functions to prosper from MRPII, they must provide reliable information to the system. Various articles have listed benefits of MRPII systems as described below. For simplicity, the benefits are shown by the functional part of the organization (Dilworth, 1993: 284-285).

1. *Inventory*: MRP helps reduce the current inventory for dependent demand items. With the explosion calculations mentioned earlier, MRP systems will only order the exact amount of components needed to produce an end-item.
2. *Production*: MRP increases the overall efficiency of the production process. With concepts such as shop floor control, where items are produced based on a priority basis, the production process continues smoothly. End-items will reach the customer on-time while the production floor is continually monitored.
3. *Sales*: MRP systems provide analysis which the sales department finds useful when promising delivery dates to customers. MRP provides "what-

if' simulation capability which allows the salespeople to accurately give promise or delivery dates to their customers.

4. *Engineering*: For potential engineering change proposals or design proposals, the MRP systems allows engineering to implement the changes at the proper time in the production process. MRP systems will allow changes to take place in an efficient manner by disrupting a minimum amount of the production floor.

5. *Planning*: As was mentioned before, the MPS is a driving force behind MRP. The MRP system again allows for simulated changes to the master schedule. Greater focus can be placed on labor force planning, equipment planning, and facility requirements. (Brady, 1987: 37)

6. *Purchasing*: MRP helps prioritize the requirements from vendors. Vendor orders can be expedited or deexpedited based on the output form the system.

7. *Scheduling*: Overall scheduling can now be prioritized with MRP.

8. *Finance*: MRP helps identify cash flows as well as future cash requirements. Based on capacity available, MRP will provide insight to make-buy decisions. (Brady, 1987: 38)

Most MRPII systems are technically sufficient; however, there are still some problems with the system. From a DoD perspective, MRP systems may hide potential audit trails for raw materials and purchased parts (Kitfield, 1988: 48-49). As Kitfield mentions in his article, DoD contractors that have both government and commercial work may be able to hide (intentionally or not) audit trails for common items. Common items in this case were helicopter parts procured by Bell Helicopter Textron for use in their commercial helicopters as well as in the Army Bell helicopters. The particular incident ended with Bell Helicopter Textron settling out of court for $69 million paid to the government for mischarging parts automatically ordered by their MRP system. This one incident obviously has not curtailed the use of MRP by government (aerospace) contractors. Shortly after the case was settled in 1988, the Defense Contract Audit Agency (DCAA) provided MRP guidelines to DoD contractors. Hopefully, these guidelines have provided the insight required by the government auditors without jeopardizing the MRP system benefits.

Ron Fisher and Guy Archer identify four reasons why MRP often fails (Fisher and Archer, 1991: 115). The fours areas are data accuracy, lead times, batch sizes, and information processing cycle time. Data accuracy particularly becomes a problem when a complex system like MRP is implemented. As an information system, MRP receives hundreds, if not thousands, of inputs regarding company products, bill of material structures, processing routes, and work centers. For simulating what-if scenarios, the MRP system obtains data consisting of sales orders, work orders, current stock levels, and purchase orders. The point here is that the output from the MRP system is only as reliable as the input the system receives. And when MRP incorporates a wide array of data input, there is potential for inaccuracy.

Lead times are defined as the elapsed time between the release of an order and the actual receipt of the order. For MRP systems, this time is fixed for the various components and raw materials. In reality, the lead time varies. One is able to see that if the fixed lead time programmed into the MRP system is too short, the receipt of items will be late. Production delays could occur and customer orders delayed. On the other hand, if programmed lead times are too long, a manufacturer could end up with excess inventory waiting to be processed. Higher inventories can increase holding costs and create inefficiencies in the production process. As stated in the article, most manufacturers want to error on the side of excess inventories in order to keep production level and the customers happy. However, this disposition creates excess buffer stocks which may actually be defeating the original intent of MRP.

Related directly to lead times with respect to inventories is the problem MRP creates with fixed batch sizes. The output which traditional economic batch quantities (EBQ) produces may not be the most prudent batch size. As manufacturers are realizing the significance of lean manufacturing with low inventories, approaches to batch size such as MRP may not produce efficient results. Companies may be able to gain a competitive edge by varying the batch size to meet current demand instead of producing a steady (fixed) amount.

The final argument made by Fisher and Archer regarding why MRP often fails relates to information processing cycle time. They assert that true what-if scenarios that simulate changes to the MPS really take several days to complete. Often, companies may respond incorrectly to an offer for new business. Acceptance of a job that will lose the company money is often the result of an MRP system that lags behind real time decision making.

MRPII and MRP systems both have produced substantial benefits as well as problems related to implementation. According to Hossein Safizadeh and Feraidoon Raafat, it is essential for top management to support the MRP system (Safizadeh and Raafat, 1986: 115). Without the support of top management, the workers often lose confidence in the system. The authors also state the importance of education for management and the workers. Initially, the organization will be resistant to change and an organized training session can alleviate many of the anxieties. With proper planning, installation and utilization of an MRP system can be successful.

With approximately 11% of U.S. manufacturers using MRP systems, there is great potential for growth. The MRP software market accounted for $2.8 billion in sales during 1993 and is increasing at a 40% rate (LaPlante, 1994: 38). MRP can be a powerful tool if used properly. Management needs to understand that MRP, in its most basic form, is an information system. Companies must effectively utilize the system before benefits can be achieved. Once the system is recognized for its potential value, MRP becomes a candidate for integration with other inventory planning and control systems. One such system is JIT manufacturing which will be discussed next.

Just In Time (JIT) Manufacturing

Tai-ichi Ohno is known as the father of JIT manufacturing. JIT was first developed and perfected in the early 1970s within the Toyota manufacturing plants as a way to successfully meet the demands of consumers (Goddard, 1986: 25). At the core of JIT is the elimination of waste. Waste, as addressed by JIT, includes improper and inefficient timing of materials through the facility, substandard quality in parts, and poorly planned supplier deliveries. To fully appreciate the evolution of JIT manufacturing, it is important to understand the influences of the Japanese culture on this manufacturing philosophy. The Japanese work ethic embraces the following ideas (Cheng and Podolsky, 1993: 2): 1) Workers are highly motivated to seek constant improvement upon that which already exists, 2) Companies focus on group involvement to share knowledge, solve problems, and achieve a common goal, 3) Work takes precedence over leisure, 4) Employees are loyal to their company for their entire lives, and 5) Individualism is not emphasized in Japan and there is an overall sense of group consciousness. In a similar fashion, L. Heiko (Heiko, 1989: 319-321) explored the underlying cultural influences the Japanese have had on JIT production. The findings are as follows:

> 1) Japanese businesses believe the customer is most important. This philosophy holds true in JIT manufacturing where consumer demand is met regardless of the level of demand. This is emphasized in the "pull" method

of production in which component parts used in production are driven or pulled by the upstream demand ultimately requested by the consumer. (Harrison, 1992: 193)

2) It is proposed that overcrowding living conditions in Japan may have influenced the emphasis on speed and efficiency. JIT manufacturing embodies this idea because production run times are minimized from material arrival to final assembly.

3) JIT attempts to minimize work-in-process inventories as well as finished goods inventories thus reducing overall plant floor space required. Again, this may relate to the dense population within Japan.

4) During JIT production, materials are stored in bins or containers for easy identification. Japanese culture has always placed emphasis on packaging (containers) with which their goods are stored and purchased.

5) JIT factories are neat and orderly with no wasted material lying around. The Japanese people are also very clean and believe in keeping the environment safe.

6) The Japanese culture relies heavily on signs and symbols in their everyday lives. In JIT production, signs are also used to signify machine usage and production line flow.

As compared to MRP which is an information system, JIT is a philosophy. The best way to understand the overall philosophy is to investigate the elements that make up JIT. The JIT elements have been depicted in figure 2.4 below (Cheng, 1993: 20).

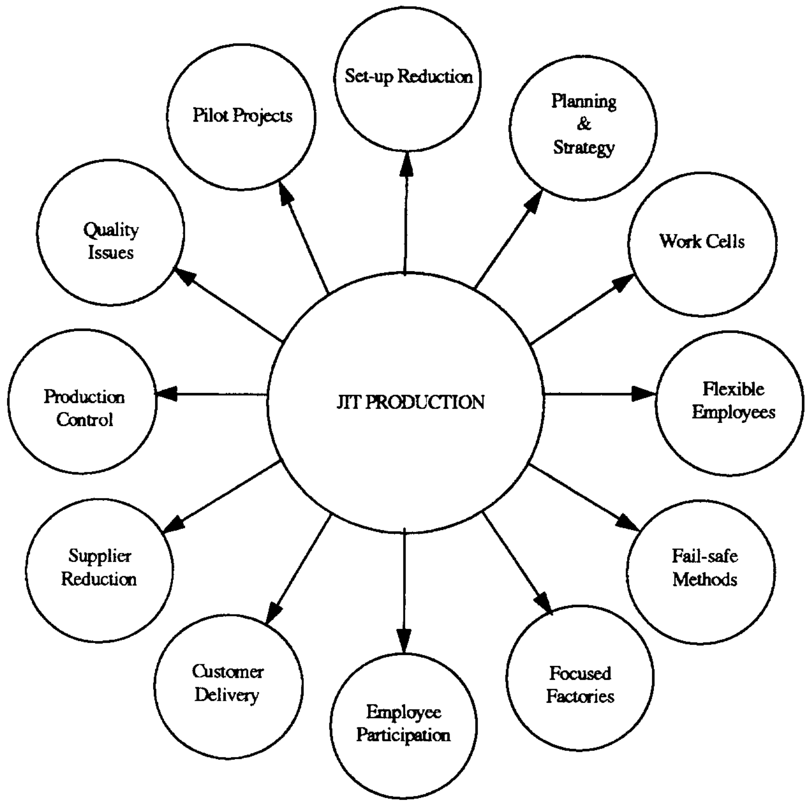

FIGURE 2.4 JIT Elements

Planning and Strategy. The main objectives of manufacturing strategy development are to set performance requirements and to ensure that the capabilities are available to accomplish the requirements. Performance requirements ultimately depend on consumer demand for the end-item. Marketing plays a major role in determining the projections in this area. Projections will generally include categorization of product lines, profit margin analysis, and demand patterns. Finally, the projections are used to set specific levels of performance for the manufacturing process.

JIT planning and strategy also focuses on the concept of demand pull manufacturing. Demand pull has a direct impact on how the production process will actually occur. Many other JIT elements stem from this overall concept which states that production only occurs as needed. Again, this concept is best explained with a figure (Cheng, 1993: 40).

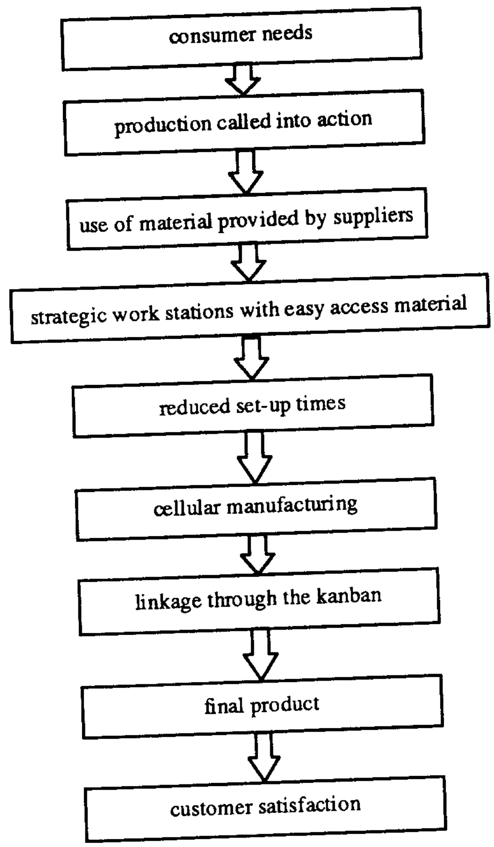

FIGURE 2.5 JIT Demand Pull Concept

Figure 2.5 above depicts a production philosophy where demand for the final product is the only component that can start the production process. This philosophy is in stark contrast to a traditional production flow (demand push concept) in which finished components from one department are immediately passed to the next department without regard to requirements.

Another important characteristic of JIT is a focus on competitive manufacturing strategies. Much of the advantages gained by JIT production are in direct response to sophisticated material handling equipment (Giust, 1993: 3-4). Overall inventories can be reduced greatly with the application of material handling equipment that delivers components to the right place, at the right time, and in the proper order. Inventory reduction can directly impact a firm's profitability (Norris, Swanson, and Chu, 1994: 63). Large inventories account for non-value added costs such as inventory carrying costs and storage costs. For competitive industries, this reduction in inventory and its associated costs may produce a price reduction on the end-item. A lower price, as compared to other manufactures, may directly impact the firms sales and profitability.

Work Cells. Work cells reduce (if not completely eliminate) transferring jobs from one department speciality to another. A cellular arrangement groups all machines and operations together in one area. N. L. Hyer (Hyer, 1989: 10) suggests that work cells are one of three concepts included in group technology. The other concepts include product design and manufacturing engineering; however, Heyer states that group technology most always focuses on cellular arrangements. The benefits of cellular manufacturing include: reduced queue (waiting) times between operations, reducing work-in-process inventories, and improving facility layout (Chase, 1995: 242).

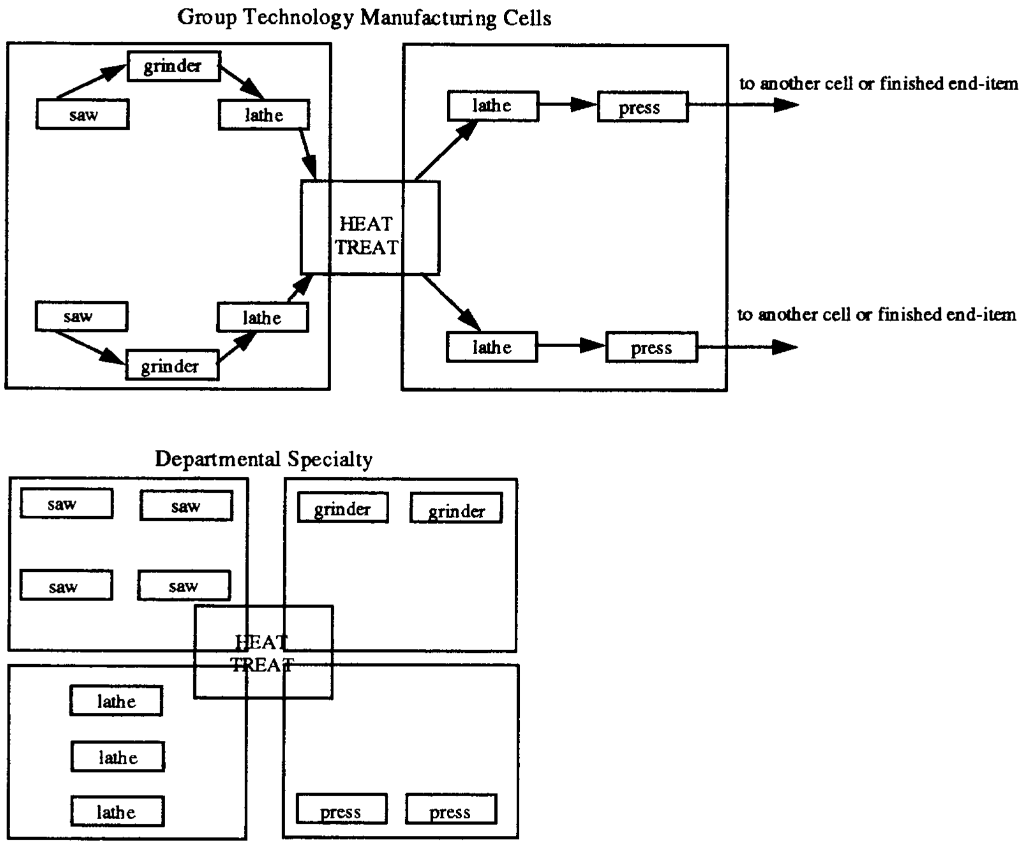

FIGURE 2.6 Manufacturing Cells and Departmental Specialty

As Chase illustrates in figure 2.6 above, the cellular arrangement groups all the needed tools together in one area. The actual arrangement of the cells (and the machines in the cells) form a U-shape. This U-shape facilitates easy movement between cells that share a common tool (i.e.: heat treating machine). This set-up decreases the overall movement (distance) that an item travels during the production phase. The U-shaped design accommodates a smooth one-piece-at-a-time flow where inventory no longer piles up between processes (Hirano, 1988: 70) The U-shaped cell is compared to the traditional departmental specialtity above where similar tools, as well as the workers who operate the tools, are located together. This set-up increases the overall movement of component parts during production and creates inefficiencies due to wasted time and energy. Hirano also notes that a traditional configuration increases the pressure on workers to meet productivity demands of an assembly line type set-up. A U-shaped design now allows the worker to move freely between processes at their own pace. A key to effective cellular arrangements is a flexible work force which will be discussed next.

Flexible Employees. Employees must be flexible in terms of the skills they possess in operating several different pieces of machinery. With a cellular layout, one or two workers will be responsible for completing multiple tasks on incoming components within their cell. Often, workers assigned to a manufacturing cell are required to gain knowledge regarding all machines in the cell. With workers having the ability to operate all machines within a cell, manufacturing can continue on a smooth pace when absenteeism is prevalent due to sickness, vacations, or shifted responsibility. Multi-functional workers are trained in problem solving techniques which includes preventative or planned maintenance. Team meetings, employee involvement, problem solving, and continuous improvement are all issues important to a multi-functional worker.

The end result of multifunctional workers is usually a reduction in job classifications (Im, Hartman, and Bondi, 1994: 1-3). Im, Hartman, and Bondi point out that in order to successfully implement multiskilled workers, training and development is required. A common fear among workers experiencing job generalization over specialization is the loss of importance to the organization. Actually, the contrary is true and, it takes training and worker involvement to emphasis this point. Workers who are able to operate various machines in addition to completing more diverse tasks are valuable to the organization. Even though initial JIT implementation may decrease the overall number of employees, job security is greatly increased for those workers that remain. This tradeoff has proven to be sufficient even in negotiations with U.S. labor organizations (Im, Hartman, and Bondi, 1994: 4).

The benefits of job enrichment programs that JIT encourages are as follows (Suzaki, 1987: 15-29): 1) employees set goals for themselves to further develop skill, 2) performing a variety of tasks reduces the monotony of the job, 3) eye and muscle strain is reduced as tasks vary throughout the day, 4) team leaders work in close consort with associates to encourage skill development, 5) employees begin to think on a grander scale to include the whole organization, 6) open communication facilitates better procedures, and 7) the teamwork approach that eventually develops promotes improved quality, safety, and cost reductions.

Fail-safe Methods. Fail-safe methods deal with quickly identifying and correcting low quality output. Fail-safing can be installed at an inspection point, in the manufacturing process itself, or in the product design (Hay, 1988: 143). At an inspection point, a low quality product would be identified and lights, buzzers, and signals may sound. Again, the use of visual signs and symbols is emphasized so that everyone knows a defective part was manufactured. The manufacturing process can also be set up to inspect itself. Per Hay, some tooling (fixtures, jigs, etc.) will not operate unless it is set up properly. The tooling actually checks itself for proper set-up and signals the operator of a problem before defective parts can be manufactured. This is often referred to as foolproofing or "poka-yoke." Foolproofing recognizes that even the best workers will occasionally make mistakes (Lu, 1986: 147). Foolproofing assures a consistent level of high quality parts without making workers fret over microscopic details--the machines will help them. Lastly, products can and should be designed with fail-safe methods in mind. Components should be designed so that there is only one correct way in which to install the part during final assembly. Product design relates directly to producibilty issues. The end-item should be relatively easy to manufacture. The more complicated the assembly process, the greater potential for defects. Ultimately, fail-safing has the consumer in mind. Fail-safing helps assure the product meets all consumer expectations.

Focused Factories. Focus within manufacturing is a) learning to focus each plant on limited, manageable sets of products, technologies, volumes, and markets and, b) implementing policies and services which are consistent with the manufacturing task (Harrision, 1992: 53). Harrison presents three approaches to focusing a factory. They are focus within the plant, product focus, and process focus. Cellular manufacturing is an example of focus within a plant. Products are often grouped by cells to create a "plant within a plant" configuration. Figure 2.7 below represents the process a traditional manufacturer might take to develop a focused factory.

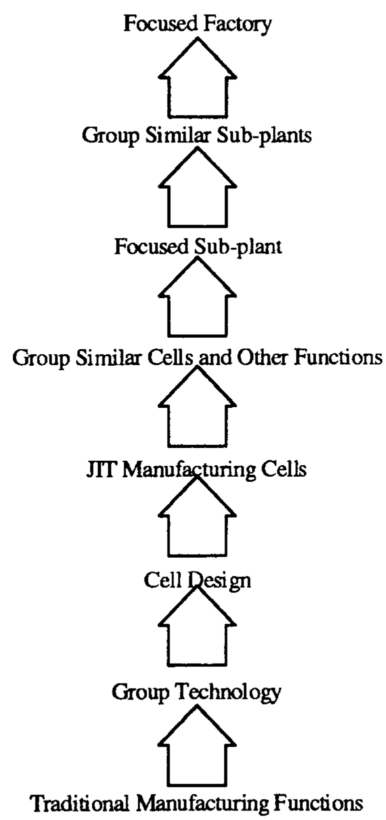

FIGURE 2.7 Focused Factory Development

When flexibility is required due to diverse product lines, the product focus will work best. If product diversity is low, the manufacturing focus can be on the process of producing high quality parts.

Focus in manufacturing was first considered by W. Skinner in 1974 (Skinner, 1974: 113-121). Skinner identified five characteristics of a focused factory.

1. Process Technologies. A manufacturing plant should focus on one process technology at a time. Any new processes endeavored at a plant should proceed with caution.
2. Market Demands. Price, leadtime, and reliability have a large impact on the manufacturing focus.
3. Product Volumes. Management should attempt to keep production volumes similar between plants in order to efficiently utilize the facilities and tooling.
4. Quality Level. Again, quality should be consistent within the various plants. Techniques such as statistical quality control are used to achieve this goal.
5. Manufacturing Tasks. With focused factories, the set-up times are reduced greatly. Now, workers are able to concentrate on producing end-items rather than changing tooling.

As Louis Guist notes, most of the push towards focused factories in the 1980s was due to the implementation of JIT concepts around the world (Giust, 1993: 6). Focused factories offer manufacturers an opportunity to achieve higher productivity and lower costs simultaneously.

Employee Participation. JIT utilizes employees to their full extent. Employees are encouraged to express ideas which may improve production processes. In Japan, a defective part or procedure, a large cost or schedule variance, or a misinterpreted control is treated as a treasure. Employees are encouraged to actively participate in uncovering problems within the organization. In contrast to many Western approaches, employees are often afraid to speak up and identify problems.

JIT organizations are generally flatter in terms of management levels. In addition to this, the focused factory concept along with cellular layout facilitates cohesive work groups. When changes are made to products or processes, the whole workforce will know about it. Properly informed workers will have a direct impact on the quality of the end-item. Figure 2.8 below focuses on communication flow within a participative JIT environment (Adair-Heeley, 1991: 38).

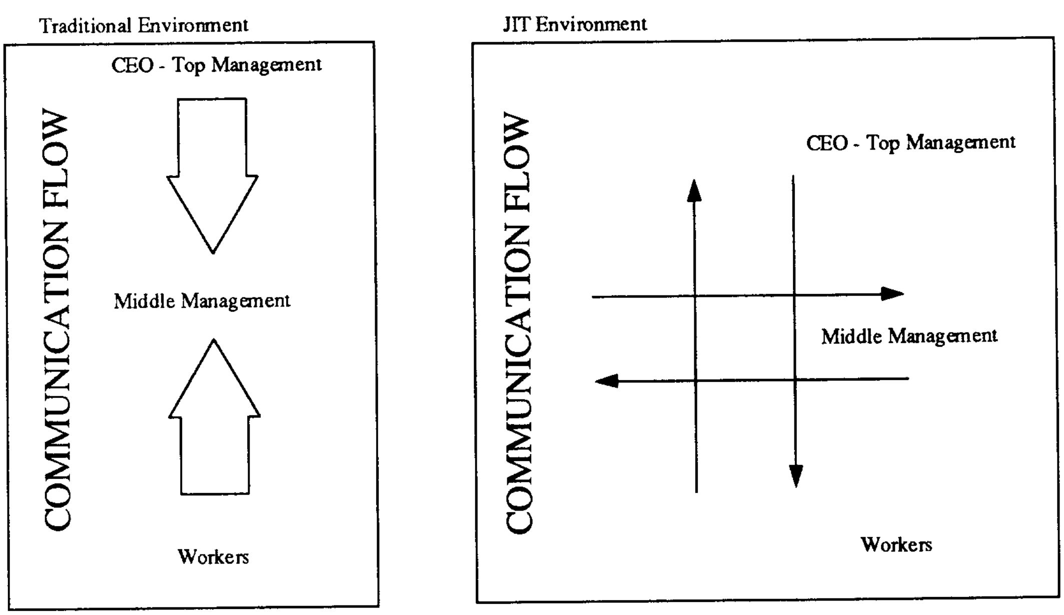

FIGURE 2.8 Communication Flow

Middle management typically serves as translator in the communication flow for traditional organizations. Often, information is lost during the process. Middle management is put under considerable pressure from above (upper level management) and below (the workers). In a participative JIT environment, communication flows vertically and horizontally. With flatter organizational structures, the workers are able to impact the responsibilities placed upon them.

Customer Delivery. Consumers rarely witness the production events that take place prior to the end-item reaching their homes or businesses. Most consumers are primarily concerned that the end-item meets their requirements and not much else. Unless, of course, they wait several weeks or months for an end-item which does meet their requirements. Now, the consumer is concerned about time as well as functionality of the product. How can manufacturing firms reduce product delays? The following steps are suggested (Cheng and Podolsky, 1993: 74). First, development teams should be used to design a product. Development teams provide all functional expertise to enter into the process thus reducing the overall pressure on design engineers. Next, product design must ensure that existing manufacturing capabilities are available and consistent with the strategic goals of the organization. Thirdly, the initial stages of product development are critical. Engineering, suppliers, planning teams, and plant floor operators should provide input to the process. Finally, program managers, who are not engineers, should lead product development teams. An engineer may overpower the team in to thinking the development is an engineering task solely.

Responsiveness is defined as the ability to satisfy customer requirements quicker than one's competitors' (Heard, 1987: 479). Therefore, it is critical that product development successfully fulfill a consumer's need. Getting an end-item to the customer sooner than your competition is beneficial only if the end-item is what they require.

Supplier Reduction. Manufacturers rely on suppliers to deliver quality parts when needed. JIT stresses that the parts arrive at the plant "just-in-time" for production of an end-item. Controlling many suppliers of the same part is difficult -- not to mention the potential quality problems that may evolve. JIT builds long term relationships with a smaller number of overall suppliers. Training for the suppliers in the use of statistical quality control and JIT concepts is often provided by the buyer of supplies (Ansari and Modarress, 1990: 53). The training effort on the part of the buyer and the acceptance of training on the side of the supplier builds a long term relationship with several advantages. Higher quality inputs are received from the supplier. With fewer suppliers, the buyer is able to devote time to the supplier regarding product design and quality measures. Communication is easier with fewer suppliers. Administrative paperwork is decreased with fewer suppliers, thus leaving more time and resources on value-added tasks. If a supplier is in a long term relationship with a buyer, cost cutting approaches can be fully developed.

Computers are playing a big role in the buyer-supplier relationship (Rowand, 1992: 8). Direct data linkup (DDL) is used by companies such as Ford Motor Company and O'Sullivan Corporation. DDL is simply a direct link via a modem and personal computer. Buyers are able to transmit data to their suppliers regarding the daily production runs and the requirements needed from the supplier. Ford Motor Company has estimated that DDL saves its suppliers nearly $16 million annually while internal company savings amount to $11.5 million per year. It is important to stress that the DDL is a two-way communication link. Many DDL systems also allow the supplier a direct link to the buyers current inventory levels. This access allows the supplier to plan effectively to meet the projected production runs of the buyer. Overall productivity has increased at Ford and O'Sullivan as a result of DDL. DDL eliminated the need for a inventory manager (middleman) to direct the incoming purchases. Now, production floor workers are able to access the system and analyze potential problems.

Industry Week provided some additional comments on JIT supplier reduction (Sheridan, 1989: 44). The article summarizes the survey results of 100 companies using JIT. The findings are as follows.

1) Since material costs represent a larger portion of manufacturing, it only makes sense to extend the JIT supplier reduction concepts to the buyer's suppliers. This idea is called full cycle JIT which not only includes the buying company, but all the suppliers as well.

2) Seventy-seven percent of the companies surveyed used dedicated souring teams with representation from quality, design, and purchasing.

3) Sourcing teams rated suppliers on quality, delivery performance history, financial stability, and top management commitment to JIT.

4) Long term supplier contracts represent 20% of the buying firm's outlays. This is expected to increase to 51% within five years.

5) Single source vendor relationships make up 46% of the buyer's expenditures.

6) A consensus was not reached among the surveyed firms on the need for electronic data interchange (EDI) or referred to as DDL above. With time, this attitude may change.

Production Control. JIT production control is concerned with the elements of the system which link, coordinate, and direct the actions of workers and machines (Cheng and Podolsky, 1993: 82). Kanbans (or Conbons) is a physical device that authorizes the production or movement of parts. Kanban means "sign" or " instruction card" in Japanese. A Conbon (Call Out Notice, Bring Out Notice) can be a card, a bin, or a light.

Again, the emphasis on visual signs is important. The conbon is used to adapt to small fluctuations in demand and the system of card, bins, or lights make up the demand "pull" method described earlier. Demand pull states that the authority to produce or supply additional parts comes from downstream operations only. Individual parts are manufactured in the order of the kanban. For suppliers, raw materials and purchased parts also follow the kanban. Lot sizes are generally determined by the bin size. A kanban system may reorder the exact amount of components removed from the bin. For the system to be a success, all employees must fully understand the system and adhere to the procedures.

Kanbans usually require the following circumstances to be prevalent in the manufacturing plant (Hay, 1988: 47-53): 1) Sub-assembly and final assembly are carried out in different facilities which would not accommodate movement of a part one at a time, 2) Work cells share a common piece of equipment thus requiring coordination for the use of the machine, 3) Work stoppages would be created by bottleneck activities or low quality parts, and 4) Critical machines can be linked to a work cell to alleviate potential work stoppages.

Quality Issues. JIT stresses quality at the source with emphasis on doing the right thing the first time (Hay, 1988: 138). Contrast this to a traditional approach where products are produced and inspected later. The bad products are scraped and the good ones are shipped. Hay identifies three JIT requirements necessary in achieving "before the fact" prevention in terms of quality. First, the product requirements must be defined. JIT quality answers the question, "Can this product always be produced so that it meets requirements?" A traditional Western approach might ask, "Can this product always be produced perfectly?" Hay believes the former question brings quality standards within the reach of manufactures. Quality must extend beyond the walls of the production facility. Quality relationships must exist with suppliers and subcontractors. In designing a product, design engineers and manufacturing engineers must work in conjunction with one another. Next, for prevention to occur, the organization must get the quality process under control. Machine operators must be given the authority to be their own inspectors. They must be trained problem solving skills and trusted by their team leaders. Another aspect of getting quality under control is problem solving. When a problem is discovered, a logical approach must be use to solve it. A problem is not truly solved unless the company has the ability to turn the problem on and off. Finally, the quality process must be kept under control. Hay points out three methods for keeping the process under control. One, increase the involvement of the machine operators. Two, implement statistical process control (SPC). And three, use fail-safe methods as described earlier.

Harrison uses a graphical approach to defining the key aspects of total quality (Harrison, 1992: 40). Figure 2.9 below describes the key aspects.

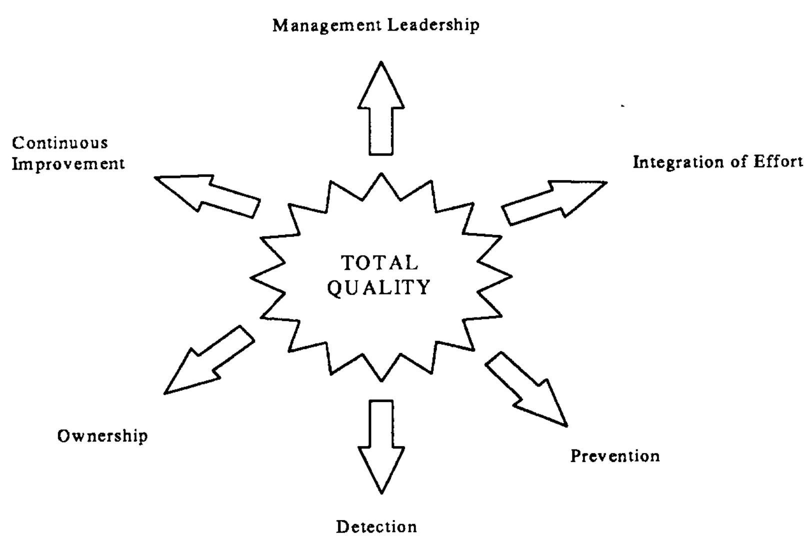

FIGURE 2.9 Total Quality Aspects

Management leadership must provide the vision for the company. Leaders must provide consistency in policy setting and company direction towards quality. Always keep in mind your customer. For internally driven demand, your customer may be the next manufacturing cell--not necessarily the ultimate consumer. It is important to know who your customer is and identify their requirements and expectations of you. Prevention deals with detecting the quality problem at the source. Detection of problems relates to visibly identifying and displaying performance for various processes. Included in detection is fail-safe devices. If you are responsible (the owner) for producing a part, then you need to correct your own errors. Don't expect someone down the line to catch your mistakes. Give employees the authority to stop the production line if necessary. Set the ultimate quality goal at zero defects in a continuous improvement approach. Abandon the acceptable quality levels (AQL) often subscribed to in the Western manufacturing culture.

Pilot Projects. Pilot projects test JIT concepts in a controlled environment. For example, instead of immediately reducing lead times by 50% throughout the company, a pilot project may attempt this goal in one area of the company. The pilot project can be a valuable learning tool. On a small scale, problems can be identified and addressed immediately. Implementing pilot projects successfully will help overall implementation of other JIT concepts. Management and workers alike are able to witness the benefits of JIT and will be more willing to accept full implementation.

Set-up Reduction. Reducing set-up time for tools is a key element in JIT manufacturing. Harrison defines set-up time as the time taken from the last item off of the last batch to the first item off the next batch (Harrison, 1992: 57). Suzaki has outlined steps that can be taken to reduce set-up times (Suzaki, 1987: 72). Figure 2.10 below identifies the concepts.

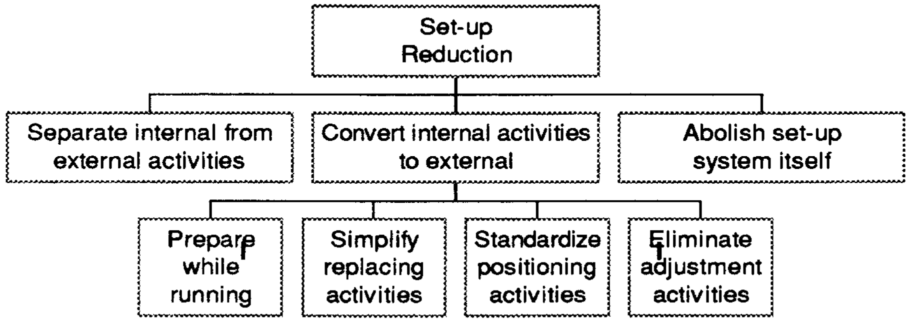

FIGURE 2.10 Set-up Time Reduction

Step one: Separate the internal set-up from the external set-up. Internal set-up is defined as the work which must be completed while the machine is stopped. External set-up is work that can be continued while the machine is running again.

Step two: Transfer work from internal set-up to external set-up. This can usually be accomplished by advanced preparation for the set-up.

Step three: Seek to further reduce internal set-up time by adding personnel, simplifying the process, or eliminating the set-up altogether.

Another way of reducing set-up is to operate parallel machines (Cheng and Podolsky, 1993: 67). Additional tool boxes located close to machines will decrease the time for set-ups. Also, Cheng suggests the use of standardized fixtures with predetermined grooves and slots for proper alignment of jigs, etc. Suzaki suggests that nearly 40-50% of set-up time is due to adjusting tooling (Suzaki, 1987: 84). Standardized fixtures could reduce this immensely.

Now that the 12 elements of JIT have been discussed, implementation will be considered. According to George Isaac, a company must implement JIT in five phases (Isaac, 1987: 40). The phases include: cleaning up the operations, effecting a company-wide cultural change, preparing logistics for JIT, implementing the program, and reviewing and monitoring the system after implementation.

Cleaning Up the Operation. An organization must have an efficiency baseline. Without a baseline, it will be impossible to measure the changes (improvements) once JIT is in place. Not only is a baseline necessary, but the organization must have a firm grasp on its current production capabilities.

Cultural Change. Implementing JIT effects all employees; therefore the concerns of management and the workers must be addressed. For management, the strategic goals of JIT will be different than the conventional thinking. This point is illustrated below in table 3.

TABLE 3

Conventional and JIT Issues

ISSUE	CONVENTIONAL THINKING	JIT THINKING
Bottom line	Cost reduction	Margin maximization
Quality vs. cost	Least cost, with acceptable quality	Top quality, with zero defects
Inventories	Large, with safety stock	Low, with continuous flow
Flexibility	Long leadtimes	Short leadtimes
Suppliers	Many, with adversarial relationships	Few, with long-term open relationship
General	Cost driven	Customer service driven

As you can see, this is a major switch for management from traditional views. For management to carry out implementation, they must have cooperation from the workers. Since JIT affects how and when items are manufactured, the workers will see major changes in their job descriptions and responsibilities. Management and the workers must work together with open communication lines for implementation to be successful.

Logistics. Logistics focuses on the supply and delivery departments currently existing in the organization. The logistics process should be accomplished concurrently with the cleaning up stage mentioned above. Since certain departments will benefit more than others with JIT in place, cost-benefit analysis should be accomplished. Supply and delivery are two departments whose overall philosophies will change dramatically. The logistics step will identify changes that will take place and the expected benefits associated with the change.

Implementing. It is recommended that implementation be accomplished in stages. This idea is consistent with the concept of pilot projects mentioned earlier where only portions of the company implement the new concept. This gradual implementation will alleviate some of the culture shock which results from major changes. Again, management and the workers must have open communication, especially during this phase.

Monitoring. In order for JIT to operate at peak performance, documentation must occur as part of the monitoring stage. Also, the JIT system will undoubtedly need refining in certain areas. Changes can be implemented quickly if documentation supports the change.

How has this Japanese philosophy caught on in the U.S.? Syed Shahabuddin argues that implementing JIT in some U.S. companies may be comparative to building a house without a foundation (Shahabuddin, 1992: 26). For U.S. companies to successfully implement JIT, they must understand the cultural changes which will need to take place.

The organization must have a sound base upon which to implement JIT philosophies. Management can not simply preach JIT to the workers; they must accept the forthcoming changes and realize that success will not happen overnight. Organizational change is difficult and JIT may be a cultural shock for many. Table 4 is a short listing of some companies that have implemented JIT and the benefits they have noticed.

TABLE 4

JIT Companies and Benefits

Xerox Corporation (Hutchins, 1986: 65)	Reduced suppliers from 5000 to 300 and implemented 2-3 year contracts with them.
Harley Davidson (Hutchins, 1986: 66)	Provided statistical quality control courses to their suppliers. Resulted in a 60% reduction in warranty repairs, scrap, and rework.
New United Motor (Hutchins, 1986: 66)	Receives daily deliveries of parts from suppliers to manufacture 900 cars per day. No excess inventory is carried overnight.
Acme Manufacturing (Payne, 1993: 83)	Manufacturing cycle time decreased from 13 weeks to 4 weeks.

JIT is definitely catching on in the U.S. Ira Smolowitz, Dean of American International College School of Business Administration, believes that JIT has implications for all business disciplines (Smolowitz, 1992: 87). He states that disciplines such as accounting, finance, marketing, and international business should not continue to function as separate entities. The business disciplines need to work together in an effort to imitate the JIT principle of teamwork. He hopes that teaching the principle of JIT is much more than just introducing another inventory management tool; rather, introducing an overall philosophy.

MRP, MRPII, and JIT

Having analyzed MRP, MRPII, and JIT, it is often asked if these systems can be effectively combined to form a hybrid MRP/JIT system. As a matter of fact, this study outlines specific research objectives which seek an answer questions regarding hybrid systems An interesting trend seemed to develop in the literature review. Literature from the mid to late 1980s included in this search focused primarily on JIT as the new and improved planning and control system. The JIT articles resulting from the 1980s greatly outnumbered the articles dealing specifically with MRP or MRPII planning and control systems. In other words, when planning and control systems were discussed, MRP and JIT were almost always treated as mutually exclusive concepts reviewed in different articles. However, as articles from the 1990s have revealed, some merit is given to hybrid MRP/JIT systems. Still, the overall number of articles which propose combining the benefits of both systems is limited. Just the fact that practitioners are exploring this hybrid option may leave one to conclude that neither system is perfect and combing the two systems may be a valuable alternative.

Just to recap, MRP and JIT have two differing objectives. MRP excels at planning complex operations while tracking a large variety of parts (Richman and Zachary, 1994: 24-25). MRP is data intensive with computer runs outputting dozens of reports. Prioritization for MRP is driven from the MPS taking into account lead times, safety stock, and explosion of internal demand. Simplicity is the key to JIT. JIT prioritizes production as and when needed with the aid of the visual kanban system to control work-in-progress. Table 5 below summarizes some of the key differences discussed to this point (Chase and Aquilano, 1995: 610). It is important to fully understand the differences between the two approaches in order to clearly see the trade-offs which will need to occur in a hybrid system.

TABLE 5

MRP and JIT Differences

CRITERIA	TRADITIONAL (MRP) ENVIRONMENT	JIT ENVIRONMENT
Based on	MPS, BOM, and inventory records	MPS and Kanban
Objectives	Plan and control	Eliminate waste and continuous improvement
Involvement process	Passive--no efforts towards change	Active--tries to improve and change system, and to lower inventory
Operation	Computerized	Simple, manual shop floor controls such as Kanban
Decision making	Top-down	Participative
	Autocratic	Democratic
	Line supervisors	Team leaders / advisors
Cost	Lowest possible	Competitive
Quality	Acceptable levels	100%
Delivery	On-time to late	Customer driven on-time
Lead times	Long	Short
Workers	Mostly followers	Contributors
Setups	Timely and less often	Quick and many
Maintenance	Fix when broken	Preventative and scheduled
Inventory	Large and required	Small and often optimal
Lot sizes	Large	Small
Queues	Good--keeps machines and worker busy	Bad--signs of bottlenecks and imbalances
Suppliers	Adversaries--low bidder gets the contract	Partners--quality, on-time parts for the long-term

Table 5 seems to outline two systems that are so far apart in their underlying goals and philosophies that combining them may seem impossible. However, here is a three step approach for phasing MRP into JIT (Flapper, Miltenburg, and Wijngaard, 1991: 329). Step one is to create a logical flow line through rapid material handling. The stock room becomes a thing of the past and all inventory is brought out to the production floor.

Either an automated guided vehicle or material handling personnel vehicle will deliver the material directly to the production area. The MRP system will still monitor the inventory; however, the location of the inventory will now be on the shop floor as opposed to the stock room. Eventually, this system will reduce the inventory levels.

Step two introduces a pull method of production. Shop floor control is handled with the Kanban system described earlier. MRPs role is to accomplish all of the external orders the production floor requires while allowing JIT to take over production floor scheduling. During step two, procedures must be developed to reduce set-up times and improve quality.

Plant layout is addressed in step three. For product groups realizing sufficient demand, cellular manufacturing arrangements should be implemented. At this stage, MRPs role includes the following: creates the master production schedule, orders external parts, and backflushes the inventory logs.

Based on the research of Flapper, many companies stop after step one. They give the following reasons.

1) Companies are afraid of losing control of the inventories.

2) Management will not make the resource commitment (time and money) to fully transition to JIT.

3) The benefits derived from step one often satisfy management. Step one usually results in lower costs, shorter lead times, decreasing inventory levels, and improved quality.

K. Stelter has identified team efforts required to provide a smooth transition to a hybrid system (Stelter, 1987: 79-80). They include: 1) cost accounting teams, 2) individual foreman, 3) manufacturing engineering teams, 4) production control teams, 5) operations management teams, and 5) data processing groups. To verify costs associated with manufacturing such as direct labor rates, cost accounting teams are provided. To facilitate actual changes on the production floor, shop foremen will explain to the workers the new facility layout, for example, will a cellular manufacturing set-up. When it comes to actually grouping production machines and tooling together in cells, the manufacturing engineers must verify the precision of the groupings. Production control personnel are needed to identify the changes in the MRP software requirements. MRPII systems under a hybrid set-up will require real-time inventory status reports for cells, final assembly, customers, and suppliers (Fuller and Brown, 1987: 395-397). Operations managers analyze statistical data from the systems to monitor the change process. Finally, data processing teams function as support to the production floor workers who may require initial training understanding the MRP/JIT interfaces. Most all of these teams will serve temporarily until a full MRP/JIT transition is made.

How would a hybrid MRP/JIT system look? Choong Lee has devised an aggregate view of an MRP planning system with JIT production and distribution as shown in figure 2.11 (Lee, 1993: 9).

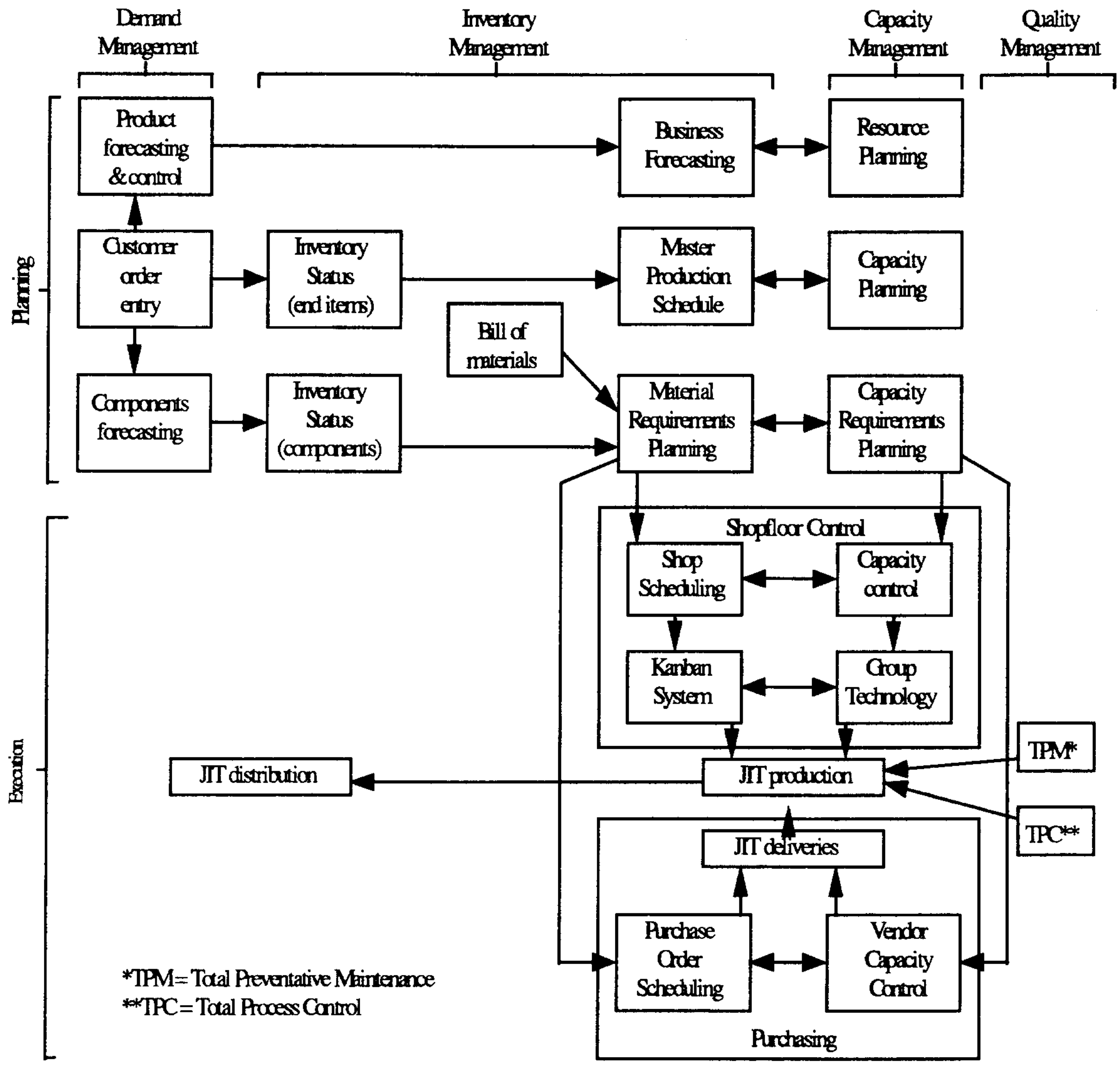

FIGURE 2.11 Hybrid MRP/JIT System

The top half of the above chart (planning area) represents a typical MRP system described in detail earlier. The MRP system includes the forecasting, scheduling, and capacity planning segments as before. The JIT system is represented by the bottom portion of the execution area to include JIT production, JIT distribution, and all the purchasing functions. Shopfloor control, the area in between MRP and JIT, acts as the interface between the two systems. As you can see, JIT concepts such as Kanban and group technology are included in this area.

Hybrid MRP/JIT systems are actually being used by companies today. For example, Michael Spencer identified major companies with a hybrid systems to include Motorola, Carrier, John Deere, Trane, Blue Bird Bus, and Verbatim Disk (Spencer, 1993: 29-30). Motorola still uses MRP for exploding the bill of material and for routings; however, they have introduced Kanban shop floor control. Currently, 75% of their components are controlled by Kanbans. Also, the have reduced set-up times to approximately ten minutes. Carrier introduced demand pull concepts in their plant in 1990. To accommodate demand pull, the facility was reconfigured. Carrier reports inventory turnover has increased 145% as a result of implementing JIT with MRP. The John Deere plant in Waterloo, Iowa was one of the first U.S. companies to introduce JIT. John Deere produces diesel engines for use in farm equipment. As a result of implementing JIT, they now deliver engines to a major source every 4 hours thus reducing finished goods inventory. Spencer notes that in no case was JIT operating without MRP. Also, once JIT was in place, the Kanban system was far superior to previous shop floor control processes.

Summary

This chapter provided background information needed to understand the importance and relevance of this research. The concepts of MRP, MRPII, and JIT were introduced. To put these concepts into a historical perspective, a brief OM history was provided. Finally, a hybrid MRP/JIT system was presented. Why even consider a hybrid system in this research? As figure 2.3 showed earlier, 70% of U.S. defense contractors have MRPII systems in place. Overall, 65,000 out of 550,000 U.S. manufacturing companies have MRPII systems. In an effort to continually improve operations, companies will seek to implement elements of JIT. MRPII systems are an expensive capital investment that should not be set aside for JIT. MRPII systems can be modified to accommodate the benefits derived from JIT. Taken together, MRP and JIT have the potential to greatly improve DoD acquisitions in terms of lower unit costs, on-time deliveries, and higher quality end-items.

III. Methodology

Chapter Overview

This study addresses several research questions as stated in Chapter I. The research questions ask:

1. Are specific industries more likely to implement JIT concepts than are others?
2. What are the customer base, manufacturing type, and production volume characteristics of companies that use both MRP and JIT?
3. Why have manufacturing firms implemented MRP and JIT?
4. How complete was the installation of MRP when JIT concepts were introduced?
5. What problems have been improved through the simultaneous use of MRP and JIT systems? What problems still exist?

The literature review from Chapter II addressed many of the above questions in both a general and a specific manner. Generally, concepts about MRP and JIT were introduced with mention of potential benefits and/or disadvantages. Specifically, a few examples were provided of manufacturing organizations that have implemented MRP, JIT, or both. This methodology chapter will draw upon the findings of the literature review by introducing the research instrument used to answer the above research questions in this study.

Research Instrument

A six page mail survey was used in this study (see appendix for complete survey). For practical purposes primarily dealing with time constraints, a survey was chosen over a case study methodology. The mail survey is also perceived as more anonymous (Emory and Cooper, 1991: 38).

The survey was sent to 350 manufacturing organizations. Seventy one surveys were returned for a rate of approximately 20%. Since this study is concerned with migration from MRP to JIT, the target population consisted only of those companies currently using some form of MRP system. To identify these companies using MRP, a pre-survey phone call and postcard was directed to various members of the American Production and Inventory Control Society (APICS). As a starting point, representatives of the Aeronautical Systems Center, C-17 System Program Office (this researcher's former employer), manufacturing division, were contacted in an attempt to identify target companies. A pre-survey postcard (questionnaire) was sent to approximately 500 companies in an effort to identify the 350 companies surveyed that employ MRP and some elements of JIT.

In consideration of the respondent's rights, a cover letter included the important benefits of participating in the survey. Participants were informed that the questionnaire was completely voluntary, and an offer was made to provide the respondent a summary of the findings if he or she was interested. Respondent confidentiality was guaranteed. The findings section will utilize the Standard Industrial Classification (SIC) rather than company or respondent names.

The questionnaire has six distinct sections. Section I was used to make comparisons across different industries and includes four questions. Respondents were asked to provide a SIC number for their organization. The SIC numbers are utilized in order to further breakdown the specific type of manufacturer being surveyed. In addition, section I addresses the following apportionment for customer base, manufacturing type, and production volume:

Customer Base (sum to 100%)

% make to stock	_____
% engineer to order	_____
% make to order	_____
% make to stock, assemble to order	_____
% other (please specify)	_____

Manufacturing Type (sum to 100%)

% project (product is engineered/designed for customer)	_____
% batch (products are made intermittently)	_____
% repetitive (high volume, few models)	_____
% continuous (high volume flow)	_____
% other (please specify)	_____

Production Volume (sum to 100%)

% project (product is engineered/designed for customer)	_____
% batch (products are made intermittently)	_____
% repetitive (high volume, few models)	_____
% continuous (high volume flow)	_____
% other (please specify)	_____

Analysis of the above information will help answer research questions one and two.

In section II, historical information is provided through four questions about the respondent. A current job title, which may provide insight into responses, is provided as well as the length of time the individual has spent in his or her current job. To provide further insight into the respondents background, the survey asks for job titles at points in time when MRP and JIT systems were installed.

MRP is the focus of section III's four questions. Specifically, section III addresses why and when MRP was implemented. As was mentioned in Chapter II, MRP can include many other elements such as MPS, CRP, Purchasing, etc., and this section identifies these elements. In particular, the respondent is asked to specify whether the elements are a) being used, or b) being implemented, or c) not applicable to their organization. Once the elements are identified, the respondent categorizes "why" MRP was installed. Finally, the respondent is asked to identify the types of problems that led to MRP implementation. Many of the reasons for MRP implementation, such as large work in process inventories and large purchased parts inventories, are provided as potential response items and were part of Chapter II discussions. Section III will answer the MRP portion of research question three.

Section IV, three questions, focuses on the length of time MRP was in place when the company decided to implement JIT. In addition to the length of time, the extent to which installation of MRP was complete (i.e.: 25% - 50% complete, etc.) when JIT implementation began is requested. Research question four will be answered from this section.

The five questions in section V addresses why JIT was implemented. Essentially, section V is formatted in a fashion similar to that used in section III; however, section V references JIT concepts instead of MRP concepts. In addition, respondents are asked to provide the extent of current use of JIT in their production operations. Responses to JIT implementation can range form less that 25% to 100% (fully implemented JIT). Section V will answer the JIT portion of research question three.

Lastly, section VI asks three specific questions about the success of integrating MRP with the JIT philosophy. Respondents are asked to identify areas of improvement as a result of the integration. Also, respondents indicated areas which are still causing problems even after integration of the two concepts. Section VI will answer research question five.

Summary

This chapter described the research design and the survey instrument developed to answer the research questions.

IV. Data Analysis

Chapter Overview

This chapter presents the results of the 71 surveys returned. As stated in Chapter III, the survey is divided into six sections. For analysis purposes, a question by question review of the results is provided. (Not every question will be analyzed below. Some general and confidential questions were asked which will not be reviewed, and leaving these questions out of the analysis does not change the results). The survey was designed to provide a logical question flow for the respondent in the areas of MRP and JIT manufacturing. The actual questionnaire and the coded results can be found in the appendix. Since the six sections of the questionnaire have multiple questions within the section, a brief explanation of question numbering is required. For example, question two in section three has three mutually exclusive response choices (a, b, or c). The question and its corresponding answer will be referred to as follows: III2 (section three, question two), III2a (section three, question two, response a), and so on. These references will be used throughout both Chapters IV and V, as well as in tables, figures, and the appendix section.

Section I

Section I asked questions about the different industries and company descriptions applicable to the respondents. Annually, the Executive Branch of the United States Government, Office of Management and Budget (OMB), publishes a standard industrial classification (SIC) manual (OMB, 1994: 1-40). The SIC is a four digit number that classifies a major grouping of industry (digits one and two), and a specific type of operation within that industry (digits three and four). For I2, the SIC was provided by 70 out of 71 respondents. Table 6 below summarizes the results. For clarity, the table lists the SIC for only digits one and two (major industry group).

TABLE 6

SIC Responses

Number of Responses	SIC	SIC Description
16	35's	Industrial and commercial machinery and computer equipment
13	36's	Electronic and other electrical equipment and components, except computer equipment
11	34's	Fabricated metal products, except machinery and transportation equipment
11	38's	Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks
4	26's	Paper and allied products
3	25's	Furniture and fixtures
3	39'2	Miscellaneous manufacturing industries
3	32's	Stone, clay, glass, and concrete products
2	37's	Transportation equipment
2	30's	Rubber and miscellaneous plastics products
1	28's	Chemicals and allied products
1	33's	Metal industries

Table 6 indicates that 51 of 70 respondents or nearly 73% fall in SIC groups 34, 35, 36, and 38. As noted earlier in Chapter II, Figure 2.3, MRPII systems can be effective in many different types of industries. A majority of companies in SIC groups 34, 35, 36, and 38 are engaged in fabrication of components and end item assembly. MRPII and JIT elements, provide many benefits to an industry with high end item quantities with assembly requirements (Chase and Aquilano, 1995: 589-590).

Section I3 addresses the apportionment for customer base, manufacturing type, and production volume. Within each part (a, b, and c), the respondent was asked to allot

100% of their company's operations. For customer base (I3a), the respondent was asked to provide information relating to the types of work actually done within the plant. For example, a make to stock item (I3a1) and a make to stock/assembly to order item (I3a4) would include items manufactured for later sale. Items are manufactured prior to actually receiving an order from a customer for that item. When an order is received, the item is taken from stock (assembled to order in some cases) and sent to the customer. In contrast, engineer to order (I3a2) and make to order (I3a3) categories require a request from a customer prior to manufacture. For engineer to order, the manufacturing firm may actually design, test, and produce an end item to meet the customer's specifications. Make to order items usually do not require the manufacturer to design the end item. The end item may be a product which the manufacturer already has the specifications to build; however, no fabrication is performed without a customer request to build the item. In addition to the above customer base categories, an "other" (I3a5) section was provided for manufacturers who did not fall into any listed category. None of the 71 respondents listed an "other" percentage response. The actual question (I3a) is listed below with the results following in tables 7a-d.

Customer Base (I3a) (sum to 100%)

% make to stock (I3a1) ______
% engineer to order (I3a2) ______
% make to order (I3a3) ______
% make to stock, assemble to order (I3a4) ______
% other (please specify) (I3a5) ______

TABLE 7a

Customer Base, Make to Stock (I3a1)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	32	45.1	32	45.1
10	20	3	4.2	35	49.3
20	30	4	5.6	39	54.9
30	40	2	2.8	41	57.7
40	50	0	0.0	50	70.4
50	60	8	11.3	49	69.0
60	70	1	1.4	50	70.4
70	80	0	0.0	50	70.4
80	90	5	7.0	55	77.5
90	100	16	22.5	71	100.0
TOTAL		71	100.0		

Table 7a above is a format which will be seen often in this analysis. The table represents basic frequency data compiled from the 71 returned surveys. The ten percent intervals from high to low were arbitrarily chosen by this researcher to provide the most insight into where respondents fall within the range of choices. For all of question I3 (a, b, and c), the low and high columns represent percentage intervals. For example, 32 respondents indicated that between 0% and 10% of their customer base is make to stock business. These 32 respondents represent 45.1% of the 71 surveyed. For make to stock data, a majority of the respondents are on either end with very low numbers in the middle ranges. The 32 respondents between 0% and 10% and the 16 respondents in the 90% to 100% range make up 67.6% of the total.

TABLE 7b

Customer Base, Engineer to Order (I3a2)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	32	45.1	32	45.1
10	20	8	11.3	40	56.3
20	30	4	5.6	44	62.0
30	40	0	0.0	44	62.0
40	50	1	1.4	45	63.4
50	60	7	9.9	52	73.2
60	70	1	1.4	53	74.6
70	80	3	4.2	56	78.9
80	90	5	7.0	61	85.9
90	100	10	14.1	71	100.0
TOTAL		71	100.0		

TABLE 7c

Customer Base, Make to Order (I3a3)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	40	56.3	40	56.3
10	20	7	9.9	47	66.2
20	30	5	7.0	52	73.2
30	40	1	1.4	53	74.6
40	50	0	0.0	53	74.6
50	60	10	14.1	63	88.7
60	70	1	1.4	64	90.1
70	80	0	0.0	64	90.1
80	90	1	1.4	65	91.5
90	100	6	8.5	71	100.0
TOTAL		71	100.0		

TABLE 7d

Customer Base, Make to Stock, Assemble to Order (I3a4)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	52	73.2	52	73.2
10	20	8	11.3	60	84.5
20	30	3	4.2	63	88.7
30	40	0	0.0	63	88.7
40	50	0	0.0	63	88.7
50	60	2	2.8	65	91.5
60	70	0	0.0	65	91.5
70	80	2	2.8	67	94.4
80	90	1	1.4	68	95.8
90	100	3	4.2	71	100.0
TOTAL		71	100.0		

The manufacturing type (I3b) is next. Again, the respondents were asked to sum their responses to 100% for the categories. Manufacturing type refers to "how" a manufacturer produces an end item. A project (I3b1) may be, for example, the building of a bridge or construction of a dam. The project includes a single definable end product usually with specified cost, schedule, and performance characteristics. A project is temporary in nature, even though completing the project, for example building a dam, may take years. The primary consideration is that the activity is not repetitive in nature. A batch operation (I3b2) is generally used when the manufacturer has a relatively stable line of products, each of which is produced in periodic groups. An example of batch production may be heavy earth moving machinery--different types of machinery will be produced through the manufacturing plant in a similar flow pattern. When end items are produced in high volume with little or no variation, repetitive production (I3b3) is utilized. Parts generally move from work station to work station along a production line in a sequence required to build the end item. Examples of repetitive production include automobile assembly, appliances, and printed circuit boards. Continuous production (I3b4) is essentially repetitive production of products that are measured by volume rather than counted (petroleum, chemicals, alcohol). The primary difference between repetitive and continuous is that continuous production does not have discrete stopping points during production. Once the process begins, the flow is "continuous" until the desired end item is achieved. Lastly, the catchall category "other" (I3b5) was available, but was not used by any respondents. The actual question (I3b) is listed below with the results following in tables 8a-d.

Manufacturing Type (I3b) (sum to 100%)

% project (product is engineered/designed for customer) (I3b1) _____
% batch (products are made intermittently) (I3b2) _____
% repetitive (high volume, few models) (I3b3) _____
% continuous (high volume flow) (I3b4) _____
% other (please specify) (I3b5) _____

TABLE 8a

Manufacturing Type, Project (I3b1)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	30	42.3	30	42.3
10	20	14	19.7	44	62.0
20	30	7	9.9	51	71.8
30	40	2	2.8	53	74.6
40	50	2	2.8	55	77.5
50	60	0	0.0	55	77.5
60	70	0	0.0	55	77.5
70	80	4	5.6	59	83.1
80	90	3	4.2	62	87.3
90	100	9	12.7	71	100.0
TOTAL		71	100.0		

TABLE 8b

Manufacturing Type, Batch (I3b2)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	42	59.2	42	59.2
10	20	13	18.3	55	77.5
20	30	8	11.3	63	88.7
30	40	1	1.4	64	90.1
40	50	0	0.0	64	90.1
50	60	0	0.0	64	90.1
60	70	1	1.4	65	91.5
70	80	3	4.2	68	95.8
80	90	2	2.8	70	98.6
90	100	1	1.4	71	100.0
TOTAL		71	100.0		

TABLE 8c

Manufacturing Type, Repetitive (I3b3)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	15	21.1	15	21.1
10	20	5	7.0	20	28.2
20	30	3	4.2	23	32.4
30	40	2	2.8	25	35.2
40	50	0	0.0	25	35.2
50	60	2	2.8	27	38.0
60	70	2	2.8	29	40.8
70	80	8	11.3	37	52.1
80	90	9	12.7	46	64.8
90	100	25	35.2	71	100.0
TOTAL		71	100.0		

TABLE 8d

Manufacturing Type, Continuous (I3b4)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	69	97.2	69	97.2
10	20	0	0.0	69	97.2
20	30	0	0.0	69	97.2
30	40	0	0.0	69	97.2
40	50	0	0.0	69	97.2
50	60	0	0.0	69	97.2
60	70	0	0.0	69	97.2
70	80	1	1.4	70	98.6
80	90	0	0.0	70	98.6
90	100	1	1.4	71	100.0
TOTAL		71	100.0		

The last question in section I dealt with production volume (I3c). The production volume categories and descriptions are exactly the same as those for manufacturing type (I3b) above. In this area however, identification is made regarding how much of the manufacturer's overall volume is consumed with project, batch, repetitive, and continuous processes. For example, it may be possible for a manufacturing firm to have 10% of its overall product line account for 90% of its production volume. In this case, if the manufacturer was fully dedicated to building a metropolitan skyscraper (project), then it is very likely this task would consume a major portion of the production volume. The actual question (I3c) is listed below with the results following in tables 9a-d.

<u>Production</u> <u>Volume</u> (I3c) (sum to 100%)

% project (product is engineered/designed for customer) (I3c1) _____
% batch (products are made intermittently) (I3c2) _____
% repetitive (high volume, few models) (I3c3) _____
% continuous (high volume flow) (I3c4) _____
% other (please specify) (I3c5) _____

TABLE 9a

Production Volume, Project (I3c1)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	31	43.7	31	43.7
10	20	15	21.1	46	64.8
20	30	5	7.0	51	71.8
30	40	2	2.8	53	74.6
40	50	2	2.8	55	77.5
50	60	0	0.0	55	77.5
60	70	0	0.0	55	77.5
70	80	5	7.0	60	84.5
80	90	3	4.2	63	88.7
90	100	8	11.3	71	100.0
TOTAL		71	100.0		

TABLE 9b

Production Volume, Batch (I3c2)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	41	57.7	41	57.7
10	20	13	18.3	54	76.1
20	30	9	12.7	63	88.7
30	40	1	1.4	64	90.1
40	50	0	0.0	64	90.1
50	60	0	0.0	64	90.1
60	70	1	1.4	65	91.5
70	80	3	4.2	68	95.8
80	90	2	2.8	70	98.6
90	100	1	1.4	71	100.0
TOTAL		71	100.0		

TABLE 9c

Production Volume, Repetitive (I3c3)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	14	19.7	14	19.7
10	20	6	8.5	20	28.2
20	30	3	4.2	23	32.4
30	40	2	2.8	25	35.2
40	50	0	0.0	25	35.2
50	60	1	1.4	26	36.6
60	70	2	2.8	28	39.4
70	80	8	11.3	36	50.7
80	90	9	12.7	45	63.4
90	100	26	36.6	71	100.0
TOTAL		71	100.0		

TABLE 9d

Production Volume, Continuous (I3c4)

Low	High	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	69	97.2	69	97.2
10	20	0	0.0	69	97.2
20	30	0	0.0	69	97.2
30	40	0	0.0	69	97.2
40	50	0	0.0	69	97.2
50	60	0	0.0	69	97.2
60	70	0	0.0	69	97.2
70	80	1	1.4	70	98.6
80	90	0	0.0	70	98.6
90	100	1	1.4	71	100.0
TOTAL		71	100.0		

Section II

For section II, only one question (II2) will be reported. The question asked the respondents to indicate how long they had held their current job. The actual question is below with the results in table 10.

Please indicate how long you have held your current job. (II2) (check one please)

a. less than 1 year _____ (value = 1)
b. 1 to 3 years _____ (value = 2)
c. 4 to 5 years _____ (value = 3)
d. 6 to 10 years _____ (value = 4)
e. More than 10 years _____ (value = 5)

TABLE 10

Time in Current Job (II2)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	4	5.6	4	5.6
2	18	25.4	22	31.0
3	26	36.6	48	67.6
4	11	15.5	59	83.1
5	12	16.9	71	100.0
TOTAL	71	100.0		

Again, this is another table format commonly used. The "value" column is simply the response coding used to tabulate the data. For example, a value of 5 means that the respondent has more than 10 years of experience in his or her current job. In table 10 above, a value of 5 occurs 12 times, representing 16.9% of the responses. The mean response value for all 71 respondents is 3.1268 which is equivalent to approximately five years on the current job.

Section III

Section III begins to identify current MRP elements in use by the respondent's company. Also, some operational problems are uncovered which are believed to have led to MRP implementation. As mentioned in Chapter II, a MRP system encompasses many elements such as a master production schedule (MPS), shop floor control (SFC), and so on. The following question (III1) was used to identify the elements considered in an organization's MRP system. Tables 11a-h provide response frequencies for assigned response values.

For question III1a-g, please indicate beside each element its current status: being used [Used; (value = 1)], being implemented now [Impl; (value = 2)], or not applicable [N/A; (value = 0)].

	Used	Impl	N/A
MRP System (III1)	[ ]	[ ]	[ ]
Aggregate Capacity Planning (III1a)	[ ]	[ ]	[ ]
Master Production Scheduling (III1b)	[ ]	[ ]	[ ]
Resource Requirements Planning (III1c)	[ ]	[ ]	[ ]
Material Requirements Planning (III1d)	[ ]	[ ]	[ ]
Capacity Requirements Planning (III1e)	[ ]	[ ]	[ ]
Shop Floor Control (III1f)	[ ]	[ ]	[ ]
Purchasing (III1g)	[ ]	[ ]	[ ]

TABLE 11a

MRP System (III1)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	67	95.7	67	95.7
2	3	4.3	70	100.0
TOTAL	70*	100.0		

*one respondent left blank

TABLE 11b

Aggregate Capacity Planning (III1a)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	67	94.4	67	94.4
2	4	5.6	71	100.0
TOTAL	71	100.0		

TABLE 11c

Master Production Scheduling (III1b)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	1	1.4	1	1.4
1	66	93.0	67	94.4
2	4	5.6	71	100.0
TOTAL	71	100.0		

TABLE 11d

Resource Requirements Planning (III1c)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	4	5.6	4	5.6
1	62	87.3	66	93.0
2	5	7.0	71	100.0
TOTAL	71	100.0		

TABLE 11e

MRP (III1d)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	1	1.4	1	1.4
1	65	91.5	66	93.0
2	5	7.0	71	100.0
TOTAL	71	100.0		

TABLE 11f

Capacity Requirements System (III1e)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	4	5.6	4	5.6
1	60	84.5	64	90.1
2	7	9.9	71	100.0
TOTAL	71	100.0		

TABLE 11g

Shop Floor Control (III1f)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	15	21.1	15	21.1
1	46	64.8	61	85.9
2	10	14.1	71	100.0
TOTAL	71	100.0		

TABLE 11h

Purchasing (III1g)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	10	14.1	10	14.1
1	57	80.3	67	94.4
2	4	5.6	71	100.0
TOTAL	71	100.0		

In an effort to verify the time period MRP systems were implemented in U.S. companies, question III2 asked when the company began installation of its MRP system. Table 12 summarizes the responses. The response values are as follows: value of 1 = prior to 1980; value of 2 = in the 1980s; value of 3 = in the 1990s.

TABLE 12

MRP Installation Time (III2)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	1	1.4	1	1.4
2	64	90.1	65	91.5
3	6	8.5	71	100.0
TOTAL	71	100.0		

Question III3 is as follows:

Why did your company begin installation of its MRP system? (Choose all that apply).

Management Decision (III3a)	[ ]
Competitive Pressures (III3b)	[ ]
Operational Problems (III3c)	[ ]
Other (III3d)________________________	[ ]

Since respondents were able to pick more than one category, the responses are not mutually exclusive. Management decisions led to installation of MRP in 51 of the 71 surveyed. In 49 cases, competitive pressures were noted as the reason for installation, while 41 respondents answered operational problems were a concern. Two respondents indicated other, but did not include a written description of the reason.

Question III4 was a follow-on question to III3c above. If respondents choose operational problems as a reason why an MRP system was installed, then they were asked to identify all (choose all that apply) the operational problems in III4 that led to MRP. Therefore, 41 respondents (or 58%) answered this question, and the results are shown in figure 4.1 below. In contrast to the 41 respondents that did have operational problems, the balance of those surveyed, or 30 respondents, did not identify operational problems leading to MRP installation. These 30 respondents represent approximately 42% of those surveyed.

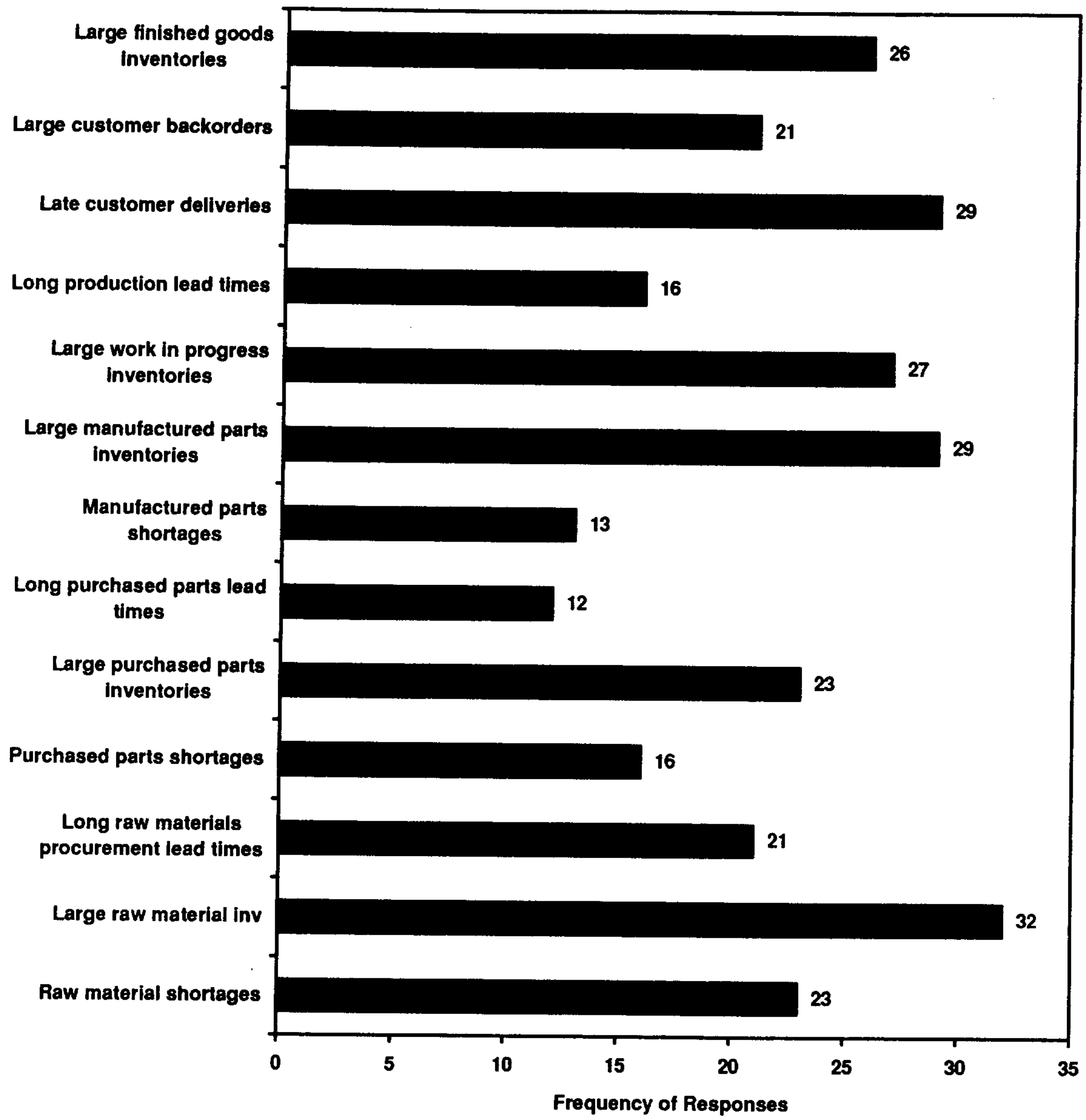

FIGURE 4.1 Operational Problems Which Led to MRP

Once more, the figure 4.1 frequencies are out of a possible 41 respondents. For example, 32 of 41, or 78%, respondents said that large raw material inventories were a reason to implement MRP. Since this is a "choose all that apply" question, respondents could potentially pick all the listed operational problems if deemed appropriate.

Hypothesis Test

The responses to Question III3 were used to test this hypothesis. The binomial test was used because the survey responses can be divided into the following two classes (C1 or C2):

C1. Those companies that implemented an MRP system because of operational problems.

C2. Those companies that implemented an MRP system for a reason other than operational problems.

The researcher arbitrarily decided that the hypothesis would be proven only if the survey results revealed that no less than seventy percent of the respondents chose "operational problems" as the reason for implementing an MRP system. The specific test was:

$$H_0 : P_0 = 0.70$$
$$H_A : P_0 < 0.70$$

The null hypothesis was rejected at both the 0.05 and the 0.10 significance levels but was marginally acceptable as the 0.01 significance level (see appendix for details).

Because the survey instrument did not include a glossary or other explanatory information about how to interpret survey questions, the possibility exists that some respondents who chose "competitive pressures" as the reason for implementing an MRP system were actually referring to operational problems that were being manifested in the form of "competitive pressures." With this thought in mind, the researcher combined the "competitive pressures" responses with the "operational problems" responses and again performed the foregoing hypothesis test. Fifty nine (59) respondents provided one or both of these reasons for implementing an MRP system. The test with the larger number (59) supported the null hypothesis at a significance level greater than 0.5. The larger number was then used to test the following statistical hypothesis

$$H_0 : P_0 = 0.90$$
$$H_A : P_0 < 0.90$$

This null hypothesis was strongly supported at the 0.01 significance level, and marginally supported at the 0.05 significance level. Because of the speculative nature of the assumption that the response "competitive pressures" can be interpreted to mean "operational problems," this line of analysis was not carried further.

Section IV

Section IV seeks to determine how long MRP implementation had been under way when the companies decided to implement the JIT philosophy, or at least some elements of JIT. Question IV1 is shown below with table 13 following with the results.

Please indicate the extent to which installation of your MRP system is complete (IV1).

Less than 25%	[value = 1]
Greater than 25% but less than or equal to 50%	[value = 2]
Greater than 50% but less than or equal to 75%	[value = 3]
Greater than 75% but less than or equal to 90%	[value = 4]
Greater than 90% but less than 100%	[value = 5]
100% (fully installed)	[value = 6]

TABLE 13

MRP Installation Completeness (IV1)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2	1	1.4	1	1.4
3	8	11.3	9	12.7
4	16	22.5	25	35.2
5	36	50.7	61	85.9
6	10	14.1	71	100.0
TOTAL	71	100.0		

Table 13 indicates that a large majority of the respondents have an MRP system at least 50% installed. Actually, 70 of 71 fall in the 50% + category.

IV2 asks the respondents to indicate how long their company operated the MRP system before deciding to implement the JIT philosophy. Key values are as follows: 1 = less than one year, 2 = one to three years, 3 = four to five years, and 4 = six to ten years. Table 14 below details the results.

TABLE 14

MRP Operation Length (IV2)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2	12	16.9	12	16.9
3	42	59.2	54	76.1
4	17	23.9	71	100.0
TOTAL	71	100.0		

Values 3 and 4 represent over 83% of the respondents in table 14 above. This indicates that these 59 companies were operating with an MRP system for at least four years before attempting to implement some JIT elements. Seventeen of them operated with MRP for many years, six to ten, before looking to JIT manufacturing.

Question IV3 asks the following, "Please indicate the extent to which installation of your MRP system was complete when you began implementing the JIT philosophy."

Less than 25%	[value = 1]
Greater than 25% but less than or equal to 50%	[value = 2]
Greater than 50% but less than or equal to 75%	[value = 3]
Greater than 75% but less than or equal to 90%	[value = 4]
Greater than 90% but less than 100%	[value = 5]
100% (fully installed)	[value = 6]

Table 15 below indicates the results.

TABLE 15

MRP to JIT (IV3)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2	7	9.9	7	9.9
3	19	26.8	26	36.6
4	32	45.1	58	81.7
5	10	14.1	68	95.8
6	3	4.2	71	100.0
TOTAL	71	100.0		

Section V

Section V identifies current JIT elements in use by the respondent's company. Again, some operational problems are uncovered which are believed to have led to JIT implementation. A JIT system encompasses many elements, of which 12 were discussed in Chapter II, such as multi-skilled workers, supplier involvement, focused factories, and so on. The following question (V1) was used to identify the elements considered in an organization's JIT system. Tables 16a-m provide response frequencies for assigned response values.

For question V1a-m, please indicate beside each element its current status: being used [Used; (value = 1)], being implemented now [Impl; (value = 2)], or not applicable [N/A; (value = 0)].

	Used	Impl	N/A
Just-In-Time (JIT) (V1)	[ ]	[ ]	[ ]
Pull method of production (V1a)	[ ]	[ ]	[ ]
Quality focus (SPC) (V1b)	[ ]	[ ]	[ ]
Multi-skilled workers (V1c)	[ ]	[ ]	[ ]
Preventative maintenance (V1d)	[ ]	[ ]	[ ]
Level schedule (V1e)	[ ]	[ ]	[ ]
Set-up time reduction (V1f)	[ ]	[ ]	[ ]
Revised plant layout (V1g)	[ ]	[ ]	[ ]
Reduced lot sizes (V1h)	[ ]	[ ]	[ ]
Supplier involvement (V1i)	[ ]	[ ]	[ ]
Small group improvement activities (V1j)	[ ]	[ ]	[ ]
Focused factory (V1k)	[ ]	[ ]	[ ]
Top management involvement (V1l)	[ ]	[ ]	[ ]

TABLE 16a

JIT (V1)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	2	2.8	2	2.8
2	69	97.2	71	100.0
TOTAL	71	100.0		

TABLE 16b

Pull Method Production (V1a)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	3	4.2	3	4.2
1	27	38.0	30	42.3
2	41	57.7	71	100.0
TOTAL	71	100.0		

TABLE 16c

Quality Focus, SPC (V1b)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	2	2.8	2	2.8
1	34	47.9	36	50.7
2	35	49.3	71	100.0
TOTAL	71	100.0		

TABLE 16d

Multi-skilled Workers (V1c)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	37	52.1	37	52.1
2	34	47.9	71	100.0
TOTAL	71	100.0		

TABLE 16e

Preventative Maintenance (V1d)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	1	1.4	1	1.4
1	40	56.3	41	57.7
2	30	42.3	71	100.0
TOTAL	71	100.0		

TABLE 16f

Level Schedule (V1e)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20	28.2	20	28.2
1	26	36.6	46	64.8
2	25	35.2	71	100.0
TOTAL	71	100.0		

TABLE 16g

Set-up Time Reduction (V1f)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	3	4.2	3	4.2
1	23	32.4	26	36.6
2	45	63.4	71	100.0
TOTAL	71	100.0		

TABLE 16h

Revised Plant Layout (V1g)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	1	1.4	1	1.4
1	21	29.6	22	31.0
2	49	69.0	71	100.0
TOTAL	71	100.0		

TABLE 16i

Reduced Lot Sizes (V1h)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	7	9.9	7	9.9
1	17	23.9	24	33.8
2	47	66.2	71	100.0
TOTAL	71	100.0		

TABLE 16j

Supplier Involvement (V1i)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	4	5.6	4	5.6
1	28	39.4	32	45.1
2	39	54.9	71	100.0
TOTAL	71	100.0		

TABLE 16k

Small Group Improvement Activities (V1j)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	8	11.3	8	11.3
1	25	35.2	33	46.5
2	38	53.5	71	100.0
TOTAL	71	100.0		

TABLE 16l

Focused Factory (V1k)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	3	4.2	3	4.2
1	36	50.7	39	54.9
2	32	45.1	71	100.0
TOTAL	71	100.0		

TABLE 16m

Top Management Involvement (V1l)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	56	78.9	56	78.9
2	15	21.1	71	100.0
TOTAL	71	100.0		

In an effort to verify the time period JIT systems were implemented in U.S. companies, question V2 asked when the company began installation of its JIT system. All 71 firms indicated that they began installation of the JIT philosophy in the 1990s.

Question V3 is as follows:

Why did your company begin to implement the JIT philosophy? (Choose all that apply).

Management Decision (V3a)	[ ]
Competitive Pressures (V3b)	[ ]
Operational Problems (V3c)	[ ]
Other (V3d)______________________	[ ]

Since respondents were able to pick more than one category, the responses are not mutually exclusive. Management decisions led to installation of MRP in 51 of the 71 surveyed. In 37 cases, competitive pressures were noted as the reason for installation, while 39 respondents answered operational problems were a concern. Four respondents indicated "other" with reasons to include: the company was bought out, a new plant manager was hired, and the Japanese are using it so it must be good.

Question V4 was a follow-on question to V3c above. If respondents choose operational problems as a reason why a JIT system was installed, then they were asked to identify all (choose all that apply) the operational problems in V4 that led to JIT. Therefore, only 39 of 71 respondents answered this question and the results are as follows in figure 4.2.

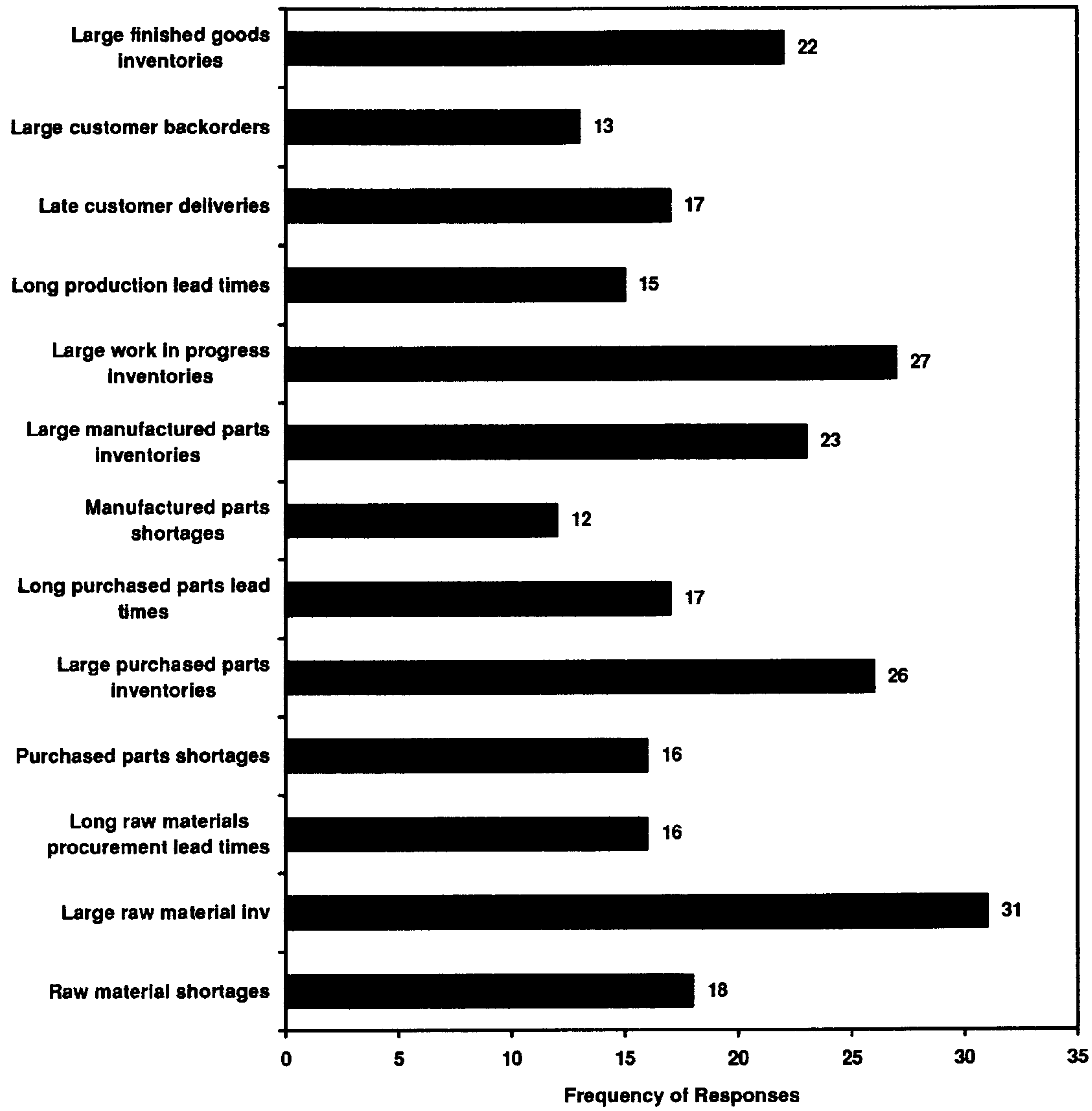

FIGURE 4.2 Operational Problems Led to JIT

Question V5 is shown below with table 17 following with the results.

Please indicate the extent to which JIT philosophy is employed in your production operations. (V5).

Less than 25%	[value = 1]
Greater than 25% but less than or equal to 50%	[value = 2]
Greater than 50% but less than or equal to 75%	[value = 3]
Greater than 75% but less than or equal to 90%	[value = 4]
Greater than 90% but less than 100%	[value = 5]
100% (fully installed)	[value = 6]

TABLE 17

JIT in Current Operations (V5)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	17	23.9	17	23.9
2	20	28.2	37	52.1
3	22	31.0	59	83.1
4	12	16.9	71	100.0
TOTAL	71	100.0		

Table 17 is consistent with findings in V2 regarding when JIT implementation began. In V2, all 71 respondents indicated the 1990s; therefore, it makes sense that JIT in current operations is fairly low. As shown above, 52.1% of the respondents operate less that 50% of their operations with JIT concepts

Section VI

The last section of the questionnaire, VI, asks questions about the success of integrating MRP with the JIT philosophy. The three questions focus on an overall impression of performance improvement, improved operational problems, and operational problems that still exist in an integrated MRP/JIT system. Question VI1 asks the following:

Please indicate the extent to which the integration of MRP and JIT has improved performance. (VI1)

a. Not at all [value = 1]
b. Minimally [value = 2]
c. Moderately [value = 3]
d. Greatly [value = 4]

Table 18 below summarizes the results for question VI1.

TABLE 18

MRP/JIT Integration (VI1)

Value	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	4	5.6	4	5.6
2	17	23.9	21	29.6
3	18	25.4	39	54.9
4	32	45.1	71	100.0
TOTAL	71	100.0		

From table 18 above, four respondents indicate no performance improvement after MRP and JIT integration. Of these four, three respondents are in the early stages of JIT implementation--less than 25% installed. The fourth respondent is 75% to 90% JIT installed, but did not provide a reason why there is no performance improvement. This still leaves 67 of 71 respondents noting at least minimal improvement after integrating MRP and JIT.

Question VI2 focuses on the same operational problems utilized throughout the questionnaire; however, here the focus is on the improvements to operational problems. VI2 asks the following:

If you chose any item other than item a (not at all) in question VI1 above, indicate which of the following problems have been **improved** by the integration of MRP with the JIT philosophy. (Choose all that apply) (VI2).

Raw materials shortages	[ ]
Large raw material inventories	[ ]
Long raw materials procurement lead times	[ ]
Purchased parts shortages	[ ]
Large purchased parts inventories	[ ]
Long purchased parts lead times	[ ]
Manufactured parts shortages	[ ]
Large manufactured parts inventories	[ ]
Large work in progress inventories	[ ]
Long production lead times	[ ]
Late customer deliveries	[ ]
Large customer backorders	[ ]
Large finished goods inventories	[ ]

Question VI2 was a follow-on question to VI1 above. If respondents chose either minimally, moderately, or greatly as a description of performance improvement due to MRP/JIT integration, then they were asked to specify which operational problems were improved (choose all that apply). Therefore, 67 of 71 respondents answered this question and the results are as follows in figure 4.3.

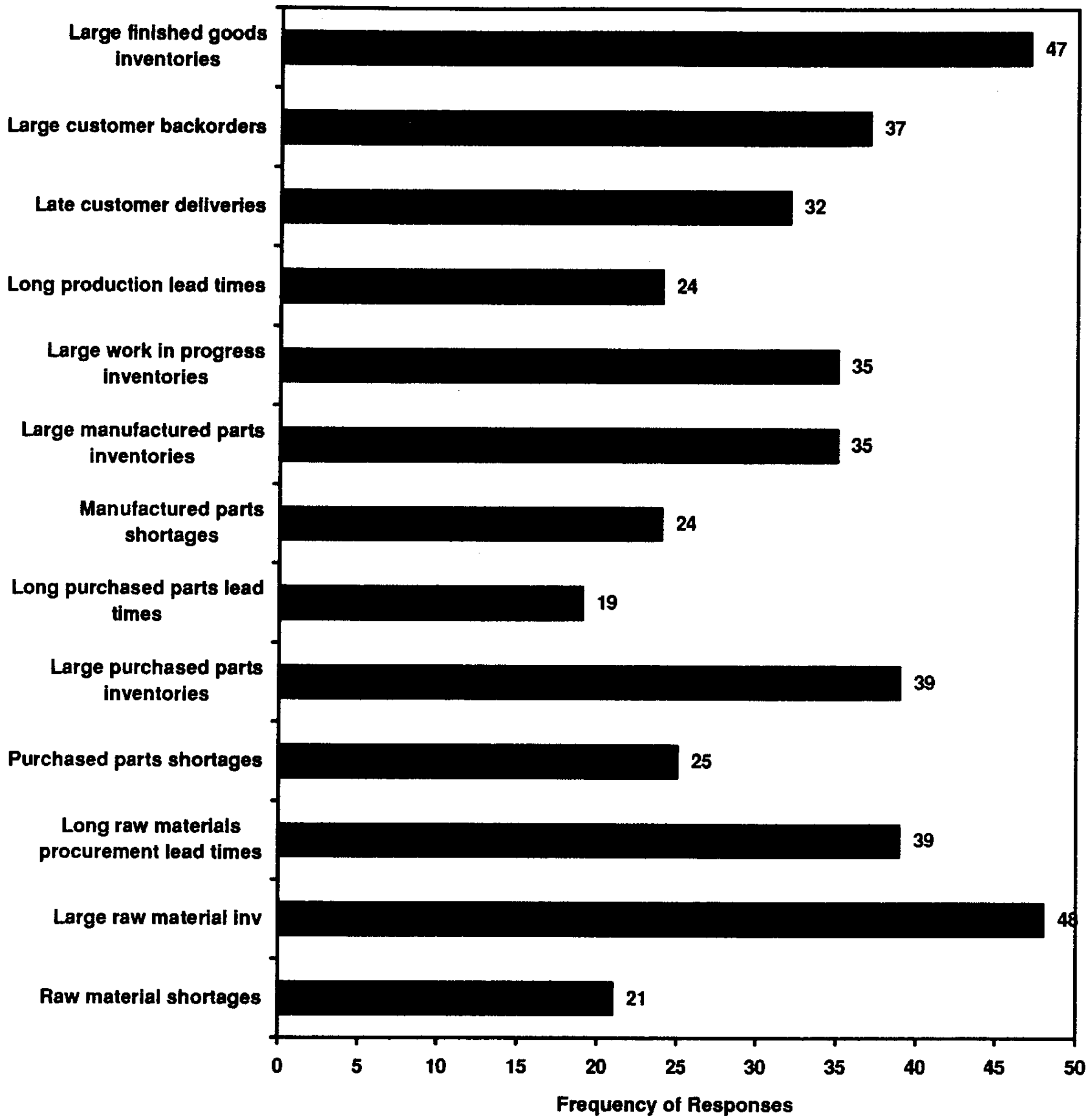

FIGURE 4.3 Improved Operational Problems with MRP/JIT

Question VI3 was addressed to all 71 surveyed companies. Again, with the same set of operational problems commonly found in manufacturing systems, they were asked to identify problems that still exist in their current MRP/JIT operating environment.

Therefore, 71 respondents answered this question (choose all that apply) and the results are as follows in figure 4.4.

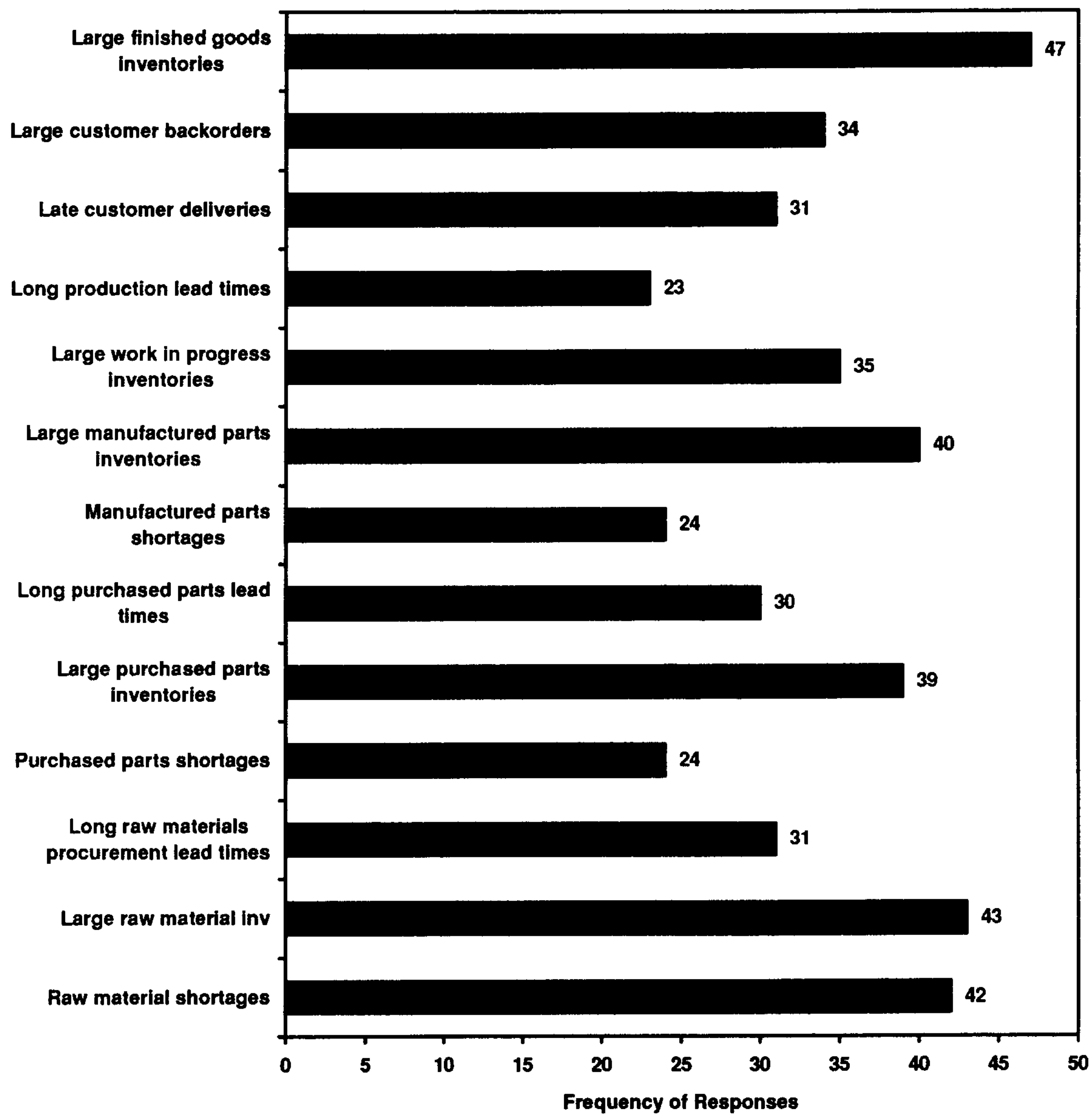

FIGURE 4.4 Continued Operational Problems with MRP/JIT

It was seen in Chapter IV that the fact that 41 of the 71 respondents implemented an MRP planning and control system due to operational problems was insufficient to support Hypothesis One (H1). Therefore, it can be concluded, afortiori, without formal testing, that the that 25 of the 71 respondents, all MRP users, implemented a JIT system due to operational problems is not sufficient to support Hypothesis Two (H2).

Table 19 below displays the data for only those respondents whose journey from the order point operating environment through the MRP operating environment into the integrated MRP/JIT operating environment followed the path expressed in Hypotheses Two (H2) and Three (H3) in Chapter I. The flow of that path and the rational for it are given in Hypotheses Four (H4) and Five (H5).

TABLE 19

MRP Progression (III4, V4, VI2, VI3)

THE "OPERATIONAL PROBLEM" WAS	LED TO MRP	LED TO JIT	IMPROVED	REMAINS
Raw Material Shortages	12 (48%)	12 (48%)	4 (16%)	16 (64%)
Large Raw Material Inv.	18 (72%)	20 (80%)	17 (68%)	14 (56%)
Long Raw Materials Lead Times	12 (48%)	10 (40%)	16 (64%)	12 (48%)
Purchased Parts Shortages	10 (40%)	11 (44%)	8 (32%)	10 (42%)
Large Purchased Parts Inv.	18 (72%)	17 (68%)	13 (52%)	12 (48%)
Long Purchased Parts Lead Times	7 (28%)	11 (44%)	6 (24%)	11 (44%)
Manufactured Parts Shortages	7 (28%)	10 (40%)	9 (36%)	10 (40%)
Large Manufactured Parts Inv.	19 (76%)	15 (60%)	10 (40%	16 (64%)
Large Work In Process Inv.	19 (76%)	18 (72%)	13 (52%)	14 (56%)
Long Production Lead Times	9 (36%)	8 (32%)	11 (44%)	9 (36%)
Late Customer Deliveries	21 (84%	11 (44%)	11 (44%)	14 (56%)
Large Customer Backorders	12 (48%)	9 (36%)	12 (48%)	12 (48%)
Large Finished Goods Inv.	13 (52%)	13 (52%)	16 (64%)	15 (60%)

Table 19 has a population of 25 respondents (out of 71) that identified operational problems leading to both MRP and JIT. These 25 respondents were specifically tracked through their progression to a hybrid MRP/JIT system. The numbers in the above table represent frequencies and percentages from the population of 25. For example, raw material shortages was the identified operational problem that led 12 out of 25 respondents (48%) to implement a MRP system. Following the same row, 12 out of 25 (48%) said raw material shortages led to JIT. After a hybrid MRP/JIT was in place, only 16% (4 of 25) reported improvements in raw material shortages. Finally, 64% of the respondents stated that raw material shortages still remain as a problem.

The last column in table 19 above, which identifies problems that still remain with an integrated MRP/JIT system, may alarm the reader. However, this researcher feels that the level of JIT implementation for these 25 companies is an important factor. It may simply be too early to tell if an integrated MRP/JIT system is truly improving the planning and control system. For the 25 respondents, the modal level of JIT implementation in their productive operations is only 25% to 50% installed. The mean level of JIT implementation is less than 50% complete. Only time will tell if the integrated system will help solve many of the operational problems identified above. Stage two of this research effort will follow-up in this area.

Summary

The analysis in this chapter was designed to follow the questionnaire flow from beginning to end. From general background information about the respondent's company and background, to MRP and JIT questions, and finally to MRP/JIT integration, the data analysis was provided. In Chapter V, this data will be used to draw conclusions about the migration towards a combined MRP/JIT manufacturing system, and the five research questions will be addressed.

V. Conclusions

Chapter Overview

This chapter will address the five research questions listed in Chapter II. With the support from Chapter IV data, the research questions will be answered. In addition, recommendations pertaining to the use of MRP and JIT planning and control systems within the DoD will be discussed. Finally, some ideas will be put forth regarding future research in this field of study.

Research Question 1

Research question one asked, "are specific industries more likely to implement JIT concepts than are others?" Based upon the 71 surveyed companies, JIT concepts are found in several different types of industries. This statement is confirmed by table 6, Chapter IV, where 12 different SIC codes were described. It is also important to note that the 12 JIT elements discussed in Chapter II could be beneficial to almost any company, operating in any industry, whether they are a batch, project, repetitive, or continuous manufacturer.

When a company or industry adopts JIT, it is adopting a philosophy regarding manufacturing planning and control. Recent history, as well as this survey, has shown that companies with some form of MRP planning and control system often hit a point of maximum benefit from that system. In other words, companies reach a point where an MRP system is no longer helping them improve productivity. Remember, MRP has served as a viable data base producing accurate and timely information. However, to improve productivity beyond MRP's constrained status, JIT is required. JIT working as a control system for the production floor, for example, can effectively improve the system. Addressing the above research question again, it seems prudent for any industry or company currently operating an MRP planning and control system to consider implementing elements of JIT to supplement their current MRP system.

Research Question 2

"What are the customer base, manufacturing type, and production volume characteristics of companies that use both MRP and JIT?," is the second research question. For customer base, the results are not conclusive towards either make to stock, engineer to order, make to order, or make to stock / assemble to order. The frequencies shown in tables 7a-d, Chapter IV, produce some interesting results. In the make to stock category, 32 respondents said 0% of their customer base is made up of this type of business. This is over 45% of the respondents. At the other extreme, 16 respondents have between 90% to 100% of their business as make to stock. The remaining 23 respondents fall randomly in between the extremes. Engineer to order follows a similar pattern. There are 32 respondents (31 with 0%) falling in the 0% to 10% range. Again, there doesn't appear to be an overwhelming conclusion in engineer to order. Make to order has 40 respondents in the 0% to 10% range. Also, six responded having between 90% and 100% as make to order. Make to stock / assemble to order had 52 responses in the 0% to 100% range. An important conclusion for the customer base research question is that even though the lower extreme (0% to 10%) may have high frequencies, the survey data required the respondents to allot 100% of their customer base. In analyzing the results, it is apparent that a majority of the companies have business in all four categories. For this reason, no one category dominates customer base. This information by itself leads to a conclusion that MRP and JIT can be effectively adopted regardless of customer base.

Based on the 71 surveyed companies, there does seem to be some patterns existing in the manufacturing type category. Twenty five respondents have between 90% and

100% of their manufacturing type apportioned as repetitive. Sixty nine out of 71 surveyed do not use continuous manufacturing. For batch production, 55 respondents have between 0% and 20% of their manufacturing type in this category. Nine respondents utilize project type manufacturing for 90% to 100% of their business, while 44 responded in the 0% to 20% category for project. Clearly, the data in this survey shows that MRP and JIT is most often used by repetitive manufacturing companies. This finding is consistent with earlier literature which touted the benefits of MRPII when production quantities are high and where some assembly is required. This finding is also consistent with early JIT implementation in Toyota Motor Company, a repetitive auto manufacturer.

Production volume is also dominated by repetitive manufacturing. Forty six respondents utilized between 50% and 100% of their volume with repetitive manufacturing efforts. Project, batch, and continuous have high frequencies on the low end of production volume. Projects take up between 0% and 30% of 51 respondent's production volume. Sixty three respondents utilize batch production only 0% to 30% of production volume, and, again, only two respondents in this survey allotted production volume to continuous manufacturing. The representative allotments between manufacturing type and production volume seem to be very similar. This result makes sense in light of the data showing very few of the respondents are project oriented manufacturers. Intensive project oriented companies would most likely find a few projects taking up a majority of their production volume, and, in this data, this is not the case.

Research Question 3

Research question three is twofold in that it asks, "why have manufacturing firms implemented MRP and JIT?" The progression to the hybrid MRP/JIT system discussed in Chapters II and IV has several steps. First, the progression from what many researchers call a "traditional or order point" manufacturing system to a MRP based planning and control system. A traditional manufacturing system usually did not provide timely and accurate information to managers and workers. This unreliable data base tended to mask inadequacies in the productive process (the machines and equipment) and in the planning and control system (i.e.: when and how much should we make, etc.). Along with the advent of powerful computers, strict data bases were born in the form of MRP and MRPII systems. Addressing the first half of research question three above regarding implementation of MRP, the survey data uncovers many reasons why MRP systems were implemented. As discussed earlier from question III3, respondents chose between management decision, competitive pressures, operational problems, and "other" as to why MRP was implemented. The operational problem category lends the most insight into definable reasons why MRP was considered a viable option. Remember, only the respondents that chose operational problems were asked to identify the specific problems in question III4. In this case, 41 respondents identified operational problems. Figure 4.1, Chapter IV, summarizes the results. As noted, the categories with "inventory" in the title were chosen most frequently. The inventory categories with their respective percent chosen include: large finished goods inventories (26 out of 41 or 63%), large work in progress or process inventories (66%), large manufactured parts inventories (71%), large purchased parts inventories (56%), and large raw material inventories (78%). The only other category out of the 13 optional choices that ranks as high as inventories is late customer deliveries at 71%. Since inventory is most often a tangible item that is visible to managers and workers, it seems evident from the data that traditional systems were not able to properly control inventory. Therefore, large inventories in all the above categories was the leading cause of MRP implementation.

The second step in the progression to a hybrid MRP/JIT system is the movement from a strictly stand-alone MRP system to implementing elements of JIT. As mentioned above, the MRP system may reach a point of maximum benefit. MRP is nothing more than an information system, and often information can be constrained. If companies are currently operating with complete knowledge regarding their information system (MRP and all the reports it generates), then implementing elements of JIT will probably help them. However, if companies have not fully utilized the powerful MRP tool, then implementing JIT may not help. In fact, implementing JIT elements into a MRP system which is not fully understood by the workers or managers could be disastrous. It is vitally important that companies implement JIT elements for the right reasons. Implementing JIT, at the expense of the current MRP system, because it is the current trend is a mistake. Managers should decide to implement JIT because they fully understand that their current MRP system, including current procedures and data bases, is maximized.

To uncover the reasons why JIT was implemented, the same series of questions regarding management decisions, competitive pressures, and operational problems was asked in question V3. It is important to keep in mind that asking why a company implemented JIT is potentially equivalent to asking what was wrong with their current MRP system. In response to question V3, 39 respondents chose operational problems and were asked to specify the problems in question V4. Figure 4.2, Chapter IV, again verifies that any inventory related category ranks high. The respective inventory categories and the percentage of respondents that chose it are as follows: large finished goods inventories (22 out of 39 or 56%), large work in progress or process inventories (69%), large manufactured parts inventories (59%), large purchased parts inventories (67%), and large raw material inventories (79%). With inventory responses leading the way and with all other operational problem categories chosen, it is evident that MRP has some problems. From this survey however, it is not possible to gauge the severity of the problem. For example, a company may have chosen large manufactured parts inventories in both instances above (i.e.: leading to MRP and leading to JIT); yet, no relative measure of the problem is provided. Inventories may have actually dropped under MRP; however, they could still be at unacceptable levels for the company. So, a respondent would still check off an inventory category simply because it was above the company's acceptable level. Even though no relative measure is provided, it doesn't take away the fact that categories were still chosen as operational problems.

The above information addressed operational problems separately for MRP and JIT implementation. Now, they will be viewed together. Of the 71 respondents, 25 chose operational problems leading to both MRP and JIT implementation. Sixteen respondents chose operational problems leading to MRP, but no operational problems leading to JIT. Fourteen respondents had no operational problems that led to MRP implementation, but they did identify operational problems leading to JIT. Finally, 16 respondents did not pick operational problems in either instance. Of the 25 respondents that identified operational problems in both instances, they consistently picked the inventory categories.

The third step in the progression to a hybrid MRP/JIT system is the actual joining of the two systems. JIT does not replace MRP. Rather, they work together. More about the hybrid system will be discussed in research question five below. For now, it is important to understand the steps which led to the hybrid MRP/JIT system.

Research Question 4

Research question four asks, "how complete was the installation of MRP when JIT concepts were introduced?" Section IV of the questionnaire addresses this area. Specifically, question IV3 found that 64 respondents had greater than 50% of their MRP systems installed before looking to JIT. This finding is consistent with the fact that 64 of 71 respondents began installation of their MRP systems in the 1980s. Also, respondents indicate that even though JIT elements were being implemented, they did not forget about their MRP system. In fact, many continued to refine their MRP systems to obtain a more complete level of installation. It may be concluded that many of the surveyed companies are still trying to fully understand their current MRP system. The data shows that simultaneous installation of MRP and JIT occurred in some cases. This seems to make sense in an environment where a hybrid MRP/JIT system is being utilized. In other words, within the overall new hybrid system, some elements of MRP work best while some elements of JIT work best. For example, the data which shows some simultaneous implementation of MRP and JIT may indicate a change in shop floor control. The JIT kanban system may take over for a MRP-type shop floor control. This simultaneous change could account for the continued change and/or refinement to the existing MRP system.

Research Question 5

Research question five asks, "with the new hybrid MRP/JIT system, what problems have been improved and what problems still exist?" The problems that have been improved are significant according to the data presented in figure 4.3, Chapter IV. The hybrid system has improved performance in all categories. Again, a relative measure of improvement was not obtained. Out of the 67 responses, 48, or 72%, indicated improvement in the large raw material category. Seventy percent noted improvement in large finished goods inventories.

From a DoD perspective, the benefits of a hybrid system are most encouraging. In this study, 13 of the surveyed companies have government contracts. Up to this point, the analysis did not separately distinguish the government versus non-government contractors because the results have been similar. The government contractors have identified the same problems and improvements as did all the other companies. As long as government regulations regarding the use of a MRP/JIT system do not get in the way, government contractors should progress similarly to non-government contractors based upon this study.

Many respondents still indicate numerous operational problems with the hybrid MRP/JIT system. Figure 4.4, Chapter IV, indicates that nearly as many respondents who noted improvement also stated that continued problems still exist. Why? The data suggests that JIT implementation is in its early stages. Fifty two percent of the respondents fall somewhere between 0% and 50% JIT installed. Also, all 71 respondents began JIT implementation sometime in the 1990s, so they have not had much time to operate the hybrid system. On the other hand, it is fairly apparent from the improvement category above that progress is on the way.

Recommendations

The hybrid MRP/JIT system must be given some time to work. Within DoD procurement centers such as the Aeronautical Systems Center (ASC) at Wright-Patterson Air Force Base, manufacturing officials should encourage the study of both MRP and JIT concepts within government contracts. Since the principles of MRP, JIT, and TQM have been highly praised within the DoD, it is time for DoD contractors to embrace the changes in planning and control systems. Considering that the implementation of a hybrid system will involve many resources (time, people, and money), DoD acquisition strategies should be tailored to encourage use of a hybrid system. Government contracting officials, through the use of different contract types and incentives for efficiency and savings, can promote positive changes to planning and control systems. All throughout the change process, it is crucial that all government officials (auditors, program managers, etc.) and contractor officials be involved. Without the involvement and support from top management, major changes such as this may not work.

Future Research

In order to get beyond some general frequency data such as reported in this study, a fairly lengthy questionnaire would be required. A common problem with a long survey would be a low response rate; however, breaking out the questionnaire into two separate mailings may help.

Likert-type scales which report various levels of problems and/or improvements would be beneficial. With this data, not only could specific categories be reported, but the significance of the responses could be analyzed as well. Even though it is useful to report an improvement, for example, it would be even better to report the improvement as a 50% improvement, and so on.

A follow-on survey also needs to have a definitions (glossary) section. A definitions section would alleviate much confusion regarding response characteristics and exclusiveness. This section would help assure the consistency among respondents who may have been exposed to different operations management terminology.

An in-depth case study of four or five contractors using a hybrid MRP/JIT system would also be beneficial to DoD, especially if the contractors had government work. Personal interviews and plant tours could provide real life representations of the concepts discussed in this study as well as fulfilling stage two of this research project.

Summary

This research has added to the body of knowledge concerning a manufacturing firm's migration from MRP planning and control systems to JIT and hybrid MRP/JIT systems. Specifically, the study analyzed the survey results from companies utilizing both MRP and JIT elements.

The study uncovered several operational problems which attributed to both MRP and JIT implementation. The study indicates that a combined MRP/JIT system still has problems, although the implementations are in their early stages. Hybrid MRP/JIT systems are being implemented in various industries with similar results. Overall, JIT implementation proved to be a concept applied only recently in the 1990s for all 71 companies surveyed.

With a fiscal year 1994 DoD procurement budget nearly $45 billion, even a 1% savings attributable to improved planning and control systems could save $450 million (Defense Department, 1994: 21). With DoD procurement budgets shrinking, this savings could produce more efficient government contractors while at the same time provide the DoD with higher quality products.

Appendix A Questionnaire

Chapter Overview

This appendix includes the complete questionnaire in the exact format sent to the surveyed companies.

Questionnaire

QUESTIONNAIRE

SECTION I

The questions in this section solicit information useful in making comparisons across different industries.

1. Please enter the name of your company. This information is needed to prevent unnecessary and annoying follow-up actions. All company names will be kept confidential.

____

2. Your company's standard industrial classification (SIC) if known

______________________________.

3. Which of the following terms best describes your company? (Please place the % on the line; each area should sum to 100%).

a. Customer Base (sum to 100%)

% make to stock _____
% engineer to order _____
% make to order _____
% make to stock, assemble to order _____
% other (please specify) _____

b. Manufacturing Type (sum to 100%)

% project (product is engineered/designed for customer) _____
% batch (products are made intermittently) _____
% repetitive (high volume, few models) _____
% continuous (high volume flow) _____
% other (please specify) _____

c. Production Volume (sum to 100%)

% project (product is engineered/designed for customer) _____
% batch (products are made intermittently) _____
% repetitive (high volume, few models) _____
% continuous (high volume flow) _____
% other (please specify) _____

SECTION II

Some of the questions on this questionnaire ask for information of a historical nature. Therefore, it is useful to know how long the respondent has been with the company and has held his/her current position.

1. Please state your current job title. ______________________________

2. Please indicate how long you have held your current job. (check one please)

   a. less than 1 year _____
   b. 1 to 3 years _____
   c. 4 to 5 years _____
   d. 6 to 10 years _____
   e. More than 10 years _____

3. If you were employed in the company when the Material Requirements Planning (MRP) system was implemented, please state your job title in the company at that time.

____

4. If you were employed in the company at the time implementation of the Just-In-Time (JIT) philosophy began, please state your job title in the company at that time.

____

SECTION III

This section asks questions about why your company implemented its MRP system. For question 1, please indicate beside each element its current status: being used [Used], being implemented now [Impl], or not applicable [N/A].

	Used	Impl	N/A
1. Material Requirements Planning System (MRP)	[ ]	[ ]	[ ]
a. Aggregate Capacity Planning	[ ]	[ ]	[ ]
b. Master Production Scheduling	[ ]	[ ]	[ ]
c. Resource Requirements Planning	[ ]	[ ]	[ ]
d. Material Requirements Planning	[ ]	[ ]	[ ]
e. Capacity Requirements Planning	[ ]	[ ]	[ ]
f. Shop Floor Control	[ ]	[ ]	[ ]
g. Purchasing	[ ]	[ ]	[ ]

2. When did your company begin installation of its MRP system?

   a. Prior to 1980 [ ]
   b. In the 1980s [ ]
   c. In the 1990s [ ]

3. Why did your company begin installation of its MRP system? (Choose all that apply).

   a. Management Decision [ ]
   b. Competitive Pressures [ ]
   c. Operational Problems [ ]
   d. Other ______________________________ [ ]

4. If you chose item 3.c. above, indicate which of the following problems led you to implement an MRP system in your company: (Choose all that apply).

a.	Raw materials shortages	[ ]
b.	Large raw material inventories	[ ]
c.	Long raw materials procurement lead times	[ ]
d.	Purchased parts shortages	[ ]
e.	Large purchased parts inventories	[ ]
f.	Long purchased parts lead times	[ ]
g.	Manufactured parts shortages	[ ]
h.	Large manufactured parts inventories	[ ]
i.	Large work in progress inventories	[ ]
j.	Long production lead times	[ ]
k.	Late customer deliveries	[ ]
l.	Large customer backorders	[ ]
m.	Large finished goods inventories	[ ]
n.	Others ______________________________	[ ]

SECTION IV

This section seeks to determine how long your MRP implementation had been under way when you decided to implement the JIT philosophy.

1. Please indicate the extent to which installation of your MRP system is complete.

a.	Less than 25%	[ ]
b.	Greater than 25% but less than or equal to 50%	[ ]
c.	Greater than 50% but less than or equal to 75%	[ ]
d.	Greater than 75% but less than or equal to 90%	[ ]
e.	Greater than 90% but less than 100%	[ ]
f.	100% (fully installed)	[ ]

2. Please indicate how long your company operated the MRP system before deciding to implement the JIT philosophy.

a.	Less than 1 year	[ ]
b.	1 to 3 years	[ ]
c.	4 to 5 years	[ ]
d.	6 to 10 years	[ ]

3. Please indicate the extent to which installation of your MRP system was complete when you began implementing the JIT philosophy.

a.	Less than 25%	[ ]
b.	Greater than 25% but less than or equal to 50%	[ ]
c.	Greater than 50% but less than or equal to 75%	[ ]
d.	Greater than 75% but less than or equal to 90%	[ ]
e.	Greater than 90% but less than 100%	[ ]
f.	100% (fully installed)	[ ]

SECTION V

This section asks questions about why your company implemented the JIT philosophy. For question 1, please indicate beside each element its current status: being used [Used], being implemented [Impl], or not applicable [N/A].

		Used	Impl	N/A
1.	Just-In-Time (JIT)	[ ]	[ ]	[ ]
	a. Pull method of production	[ ]	[ ]	[ ]
	b. Quality focus (SPC, In-process checks)	[ ]	[ ]	[ ]
	c. Multi-skilled workers	[ ]	[ ]	[ ]
	d. Preventative maintenance	[ ]	[ ]	[ ]
	e. Level schedule	[ ]	[ ]	[ ]
	f. Set-up time reduction	[ ]	[ ]	[ ]
	g. Revised plant layout	[ ]	[ ]	[ ]
	h. Reduced lot sizes	[ ]	[ ]	[ ]
	i. Supplier involvement	[ ]	[ ]	[ ]
	j. Small group improvement activities	[ ]	[ ]	[ ]
	k. Focused factory	[ ]	[ ]	[ ]
	l. Top management involvement	[ ]	[ ]	[ ]
	m. Other (please explain)			

____

2. When did your company begin implementing elements of the JIT philosophy?

a. Prior to 1980	[ ]
b. In the 1980s	[ ]
c. In the 1990s	[ ]

3. Why did your company begin to implement the JIT philosophy? (Choose all that apply).

a. Management Decision [ ]
b. Competitive Pressures [ ]
c. Operational Problems [ ]
d. Other ______________________________ [ ]

4. If you chose item 3.c. above, indicate which of the following problems led you to implement the JIT philosophy in your company: (Choose all that apply).

a. Raw materials shortages [ ]
b. Large raw material inventories [ ]
c. Long raw materials procurement lead times [ ]
d. Purchased parts shortages [ ]
e. Large purchased parts inventories [ ]
f. Long purchased parts lead times [ ]
g. Manufactured parts shortages [ ]
h. Large manufactured parts inventories [ ]
i. Large work in progress inventories [ ]
j. Long production lead times [ ]
k. Late customer deliveries [ ]
l. Large customer backorders [ ]
m. Large finished goods inventories [ ]
n. Others ______________________________ [ ]

5. Please indicate the extent to which JIT philosophy is employed in your production operations.

a. Less than 25% [ ]
b. Greater than 25% but less than or equal to 50% [ ]
c. Greater than 50% but less than or equal to 75% [ ]
d. Greater than 75% but less than or equal to 90% [ ]
e. Greater than 90% but less than 100% [ ]
f. 100% (fully installed) [ ]

SECTION VI

This section asks questions about the success of integrating MRP with the JIT philosophy.

1. Please indicate the extent to which the integration of MRP and JIT has improved performance.

a.	Not at all	[ ]
b.	Minimally	[ ]
c.	Moderately	[ ]
d.	Greatly	[ ]

2. If you chose any item other than 1.a., indicate which of the following problems have been **improved** by the integration of MRP with the JIT philosophy. (Choose all that apply).

a.	Raw materials shortages	[ ]
b.	Large raw material inventories	[ ]
c.	Long raw materials procurement lead times	[ ]
d.	Purchased parts shortages	[ ]
e.	Large purchased parts inventories	[ ]
f.	Long purchased parts lead times	[ ]
g.	Manufactured parts shortages	[ ]
h.	Large manufactured parts inventories	[ ]
i.	Large work in progress inventories	[ ]
j.	Long production lead times	[ ]
k.	Late customer deliveries	[ ]
l.	Large customer backorders	[ ]
m.	Large finished goods inventories	[ ]
n.	Others ______________________________	[ ]

3. Indicate which of the following problems **still exist** in your current MRP/JIT operating environment. (Choose all that apply).

a.	Raw materials shortages	[ ]
b.	Large raw material inventories	[ ]
c.	Long raw materials procurement lead times	[ ]
d.	Purchased parts shortages	[ ]
e.	Large purchased parts inventories	[ ]
f.	Long purchased parts lead times	[ ]
g.	Manufactured parts shortages	[ ]
h.	Large manufactured parts inventories	[ ]
i.	Large work in progress inventories	[ ]
j.	Long production lead times	[ ]
k.	Late customer deliveries	[ ]
l.	Large customer backorders	[ ]
m.	Large finished goods inventories	[ ]
n.	Others ______________________________	[ ]

Appendix B Hypothesis Test

Chapter Overview

This appendix includes the hypothesis testing referenced in Chapter IV.

Test

A.

N = 71 respondents (total survey population)
$X_{observed}$ = 41 respondents with operational problems leading to MRP
prob (p) set by researcher at 70% = 0.70
alpha = .01 $\quad z = -2.33$

Solving for X_{crit} at 70% confidence interval:

$H_0 : P_0 = 0.70$
$H_0 : P_0 < 0.70$

$((X / 71) - 0.70)) / \text{sqrt}\ [((p)\ (1 - p)) / 71] = -2.33$

$X / 71 = 0.70 - 2.33\ (.054385)$

$X = 40.703 = X_{crit}$

same test with alpha = .05 $\quad z = -1.645$

$X = 43.348 = X_{crit}$

same test with alpha = .10 $\quad z = -1.28$

$X = 44.759 = X_{crit}$

B.

N = 71 respondents (total survey population)
$X_{observed}$ = 41 respondents with operational problems leading to MRP
prob (p) set by researcher at 90% = 0.90
alpha = .01 z = -2.33

Solving for X_{crit} at 70% confidence interval:

$H_0 : P_0 = 0.90$
$H_0 : P_0 < 0.90$

$((X / 71) - 0.90)) / \text{sqrt} [((p) (1 - p)) / 71] = -2.33$

$X / 71 = 0.90 - 2.33 (.0356)$

$X = 57.11 = X_{crit}$

same test with alpha = .05 z = -1.645

$X = 58.84 = X_{crit}$

C.

$N = 71$ respondents (total survey population)

$X_{observed} =$ 59 respondents with operational problems and competitive pressures leading to MRP

prob (p) set by researcher at 70% = 0.70

alpha = .01 z = -2.33

Solving for X_{crit} at 70% confidence interval:

$H_0 : P_0 = 0.70$
$H_0 : P_0 < 0.70$

$((X / 71) - 0.70)) / \text{sqrt}\ [((p)\ (1 - p)) / 71] = -2.33$

$X / 71 = 0.70 - 2.33\ (.054385)$

$X = 40.703 = X_{crit}$

same test with alpha = .05 z = -1.645

$X = 43.348 = X_{crit}$

same test with alpha = .10 z = -1.28

$X = 44.759 = X_{crit}$

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Vita

Captain Scott A. Koehler is from Charles City, Iowa. He graduated in 1987 from Iowa State University of Science and Technology with a Bachelors degree in Business Administration. After receiving his commission into the United States Air Force through Officer Training School, Captain Koehler was assigned to the C-17 System Program Office (SPO), Financial Management Division, at Wright-Patterson AFB, Ohio.

During his tour in the C-17 SPO, Captain Koehler served as a cost analyst for the aircraft systems integrated product team. He performed cost estimating and budget planning to develop annual C-17 cost projections. Specifically, he estimated nearly $2.0 billion worth of contractor manufacturing tooling requirements necessary to build 120 C-17 aircraft. On a quarterly basis, Captain Koehler provided the SPO director with a financial health analysis of the prime contractor. This analysis helped predict future survivability of the prime contractor in a shrinking defense industrial base.

In 1994, Captain Koehler entered the Air Force Institute of Technology at Wright-Patterson AFB, Ohio, and graduated in 1995 with a Masters degree in Cost Analysis. He was subsequently assigned to the Air Force Cost Analysis Agency, Crystal City, Virginia.

Permanent Address: 308 Charles St.
Charles City, IA 50616

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Scott A. Koehler, Captain, USAF

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13. ABSTRACT *(Maximum 200 words)*

Manufacturing planning and control systems play an important role in an organization's effectiveness. Over the past twenty to thirty years, U.S. manufacturing companies have faced increasing competition for market share from Japanese and other Pacific rim countries. This thesis will investigate the evolutionary path followed by manufacturing companies that have implemented various manufacturing planning and control systems. Specifically, Materials Requirements Planning (MRP) and Just In Time (JIT) production will be analyzed. Why is this an area of interest to American manufacturers? MRP is an American development, and many American manufacturers have implemented MRP systems since the late 1950's. However, recent emphasis on time-based competition within manufacturing organizations has caused many of those companies to supplement their MRP systems with a JIT system. In other instances, a JIT system has supplanted the MRP system. MRP and JIT are not competing approaches to planning and controlling manufacturing operations; each offers benefits not offered by the other alone. This fact suggests that the most ideal manufacturing planning and control system will probably embody elements of both MRP and JIT.

14. SUBJECT TERMS
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