1991

A study of the relative importance of JIT implementation techniques using the analytic hierarchy process model

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by

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A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE

Department: Industrial Manufacturing and Systems Engineering
Major: Manufacturing Engineering

Iowa State University
Ames, Iowa

1991

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CHAPTER I. INTRODUCTION

The United States (U.S.) was regarded as the world's productivity and manufacturing leader until the early 1960s. Later, over the period 1970 to 1990, Japan has supplied a growing share of the dollar value of total U.S. imports. The extent of the growth of Japanese imports in the U.S. market has prompted U.S. managers to examine the systems that are seen as contributing to Japanese success. This examination has resulted in the perception that JIT (just-in-time) is the critical difference. Manufacturers have become aware of quality , productivity, and cost issues that will ultimately determine their survival. General Motors, Ford, General Electric, and others have not only adopted JIT as a philosophical goal, but also are actively assisting their suppliers in switching to the same philosophy [41]. Those large companies have invested heavily in the transition, and have used relatively small projects to develop their skills and knowledge of JIT. The transition knowledge is proprietary and is apparently not shared with industry in general.

A reasonable response by other traditional manufacturers to these successes is to change their existing manufacturing practices to become more competitive. However this type of response is not without risk. Lee [29] said that

> ...the system presents more than techniques. Instead Japanese techniques are borne in philosophy, ... Those companies who have randomly implemented pieces of the Japanese systems have found their attempts to improve productivities have failed.

This implies that broad strategic planning is required for JIT to be successful. Although a basic concept of JIT is simplification, simplification is not so simple to achieve.

Statement of Purpose

The purpose for this research is to investigate appropriate ways for manufacturers to successfully implement JIT systems. In order to accomplish this purpose, a survey is undertaken to examine the relative importance of selecting JIT implementation techniques and the AHP (Analytic Hierarchy Process) model is used to analyze the information from the experts. The results of this study will give some insight into the relative importance of JIT techniques with respect to the goal of increasing manufacturing efficiency and effectiveness. The results may give some direction to those firms who are interested in restructuring their own production systems according to JIT concepts.

Brief Overview of Paper

Chapter 2 presents an overview of JIT systems and concepts, and the factors to consider in implementing JIT systems. The methodology and application of analytical hierarchy process (AHP) model are described in Chapter 3, followed by the research design, the survey methodology, and the statistical analysis in Chapter 4. Statistical tests were based on data collected from 28 subjects. The summary and conclusions in Chapter 5 finalize the study.

CHAPTER II. AN OVERVIEW OF JIT SYSTEMS

An Overview of the Production Function

The cost of a product is based on raw materials, machines, labor, selling expense, warehousing, and overhead expenditures. The purpose of economical production is to produce a product at a profit. This implies that the cost must be acceptable and competitive.

In order to produce competitively, it is important that the product be so designed that the cost associated with material, manufacturing, and storage be as low as possible.

There are a number of ways that industries can be classified. Broadly speaking, they can be classified as: 1) Mass production 2) Moderate production 3) Job lot production. Mass production type products are produced continuously at high volume for a considerable period of time. For the moderate production operations, parts are produced in relatively large quantities and perhaps continuously, but the output may be more variable than for mass produced parts and often more dependent upon size of order. The job lot industries are more flexible, and their production usually limited to lots closely attuned to size of orders or expected sales. Employees must be more highly skilled, performing various tasks depending upon the part or assembly being made.

Pre-JIT job-shop production

U.S. industry has become highly proficient in job-shop manufacturing management in the last twenty years. Job-shop manufacturing is used in low to medium volume production quantities for a wide variety of products. The job-shop manufacturer must be able to react quickly to an unpredictable and changeable mix of orders. The flow of the product through the factory is considerably more complex than in a continuous flow manufacturing environment. Most organizations build high buffers of in-process inventory between department sand operations to ensure production capacity is utilized to its fullest extent.

A computer-based manufacturing management system known as material requirements planning (MRP I) and then manufacturing resources planning (MRP II) was developed in the United States in the 1960s to deal with inventory problems. MRP I concept is a material planning and scheduling system. But under MRP II, there are three levels of scheduling:

Master schedule - quantity and date for completion of end items

Material requirement planning - scheduling the completion and start dates of the components and raw materials dependent on the master schedule.

Shop floor control - scheduling the operations performed on a component between MRP start and finish dates.

Then the JIT concept has been put into a coherent manufacturing strategy.

JIT production

The just-in-time production philosophy evolved from a unique concept of inventory and quality control developed by Toyota Motors. Just-in-time represents a whole process of continuous improvement within a manufacturing area. It is a continuous process of improving the production system to produce the right products in the right quantity and at the right time [42]. Manufacturing is designed to eliminate waste in the production process for the purpose of reducing cost, improving quality, and increasing flexibility and productivity. The just-in-time philosophy in manufacturing is based on the concept of a balanced, synchronized flow of raw materials and in-process inventory. Balancing the flow of inventory is of prime importance and is more important than speed [42].

JIT Implementation Techniques

JIT systems can be implemented using various techniques. The following section will describe various methods that can be implemented independently or collectively to achieve management's goal of improving manufacturing efficiency and effectiveness.

Setup time reduction

Setup time is the time taken to adjust the machine to produce another type of product. It is the time between runs when the machine does not produce anything. Excessive setup time reduces the productivity of the machine. Traditionally, a large batch size is used in order to compensate for a long setup time. As a result, lead times and inventory levels are increased. This, in turn, decreases the flexibility of the system to adapt to change. Accordingly, reducing setup time will increase machine productivity, decrease batch sizes, decrease lead times, decrease inventory levels, and increase the flexibility of the system.

Setup time reduction is a basic JIT implementation method. Toyota Motors has made a systematic attempt to reduce setup time in their operations. They have achieved remarkable reductions leading to what they call single setup, meaning setup times of less than ten minutes and frequently of under one minute, namely one-touch setup [37].

As with other aspects of JIT, reduction of setup time is regarded as an area of continual improvement [33]. The following five basic steps should be taken to reduce setup time [37,45]:

1. Identify those setups times that can be reduced,
2. Separate internal from external setups,
3. Convert to the extent possible from internal to external setup,
4. Reduce the time of adjustment, and
5. Eliminate the setup itself.

Identification of those setups to be reduced first is done by starting out with a small number of similar setups. The focus is directed at reducing their setup time. What is learned from these selected setups is applied to other setups.

Separating internal setup from external setup operations involves those areas of setup requiring the machine to be stopped (internal setup) and those allowing the machine to keep running (external setup). By simply separating and organizing external and internal operation, internal setup time (unavoidable machine shutdown) can be reduced by 30 to 50 percent [21].

Converting the maximum number of internal setups to external setups results in performing the maximum number of setups while the machine is operational. This is a powerful principle without which the single minute setups are not achievable.

Reducing adjustment time is very important to shortening the total setup time. After the tooling is in place, adjustment usually takes about 50 to 70 percent of the internal setup time [21]. Simple marking of setup positions on the equipment or measuring instruments associated with the equipment can be a way of reducing this time.

Eliminating the setup time altogether is the final step in setup reduction. Here, two possibilities exist. First, by standardizing the parts so that the product range is reduced, each part may be used on a wide variety of products. Second, the required parts can be made simultaneously, either on the same machine or on parallel machines.

Several techniques can be used to implement those concepts.

- Compared with standard fasteners such as nuts and bolts, quick fasteners can significantly reduce setup time.
- The use of a mechanical aid, such as a ram can also reduce setup time, especially for heavier fixtures.
- Maximum standardization of setups will help routinize setup operations. Nevertheless, this may only be cost effective for part of the operations.
- Arranging setup operation to be carried out by two people simultaneously will reduce internal setups [37].

Setup time reduction is more than just an engineering project because it requires employee involvement. Setup people and operators know more about the process and their machines than anyone else. Therefore, involving these people in setup time reduction will increase the chances of success.

In short, reduced setup time and setup cost make smaller production lot size practicable. This, in turn, will reduce inventory size and increase the flexibility of the production system.

Uniform plant load

To balance and synchronize the product flow, a uniform plant load is required. Such a load involves cycle times and load leveling.

Cycle time deals with the rate of production. Cycle time under JIT is a measure of the final demand for the product. The principle of cycle time states that the production rate must equal the demand rate for the product, and not be equal to the ability to produce. In other words, the production of all pieces and parts of the finished product should be synchronized with the final demand rate and should be constrained only by bottlenecks within the process. The main purpose is to keep the flow smooth. The principle not only applies to the manufacturing process, but extends to the linking between the buyer and the vendor.

Level loading deals with the product itself. Whereas cycle time deals with the running of products at the right rate. Even though the cycle time of the process may be set at the required rate, each type of product will not necessarily be produced at the rate required. For example, if a monthly plan calls for the production of 180 units of A and 120 unit of B, then each day 6 units of A and 4 units of B will be produced rather than producing 180 units of A within the first 18 days and 120 units of B within the following 12 days. In this manner, work-in-process and final product inventory levels are minimized and throughput is improved.

Group technology

In traditional shop floor layout, the facilities are organized by departmental specialty, where each department specializes in a type of equipment or technology. This is called job-shop manufacturing. In this clustered type of layout, materials move from department to department which often requires significant material handling resources and precludes the possibility of visual production control.

In a JIT system, the facilities are laid out by product rather than by function. This is called a work cell. The equipment is arranged in the order in which operations are to be performed on the family of the products. This way of organizing manufacturing is called group technology and had its origins in the USSR. This type of manufacturing is also called cellular manufacturing.

Within this environment, products flow one at a time from machine to machine which is different from the traditional system in which the product often moves in batches from one operation to the next operation [4,25]. Cellular manufacturing reduces space requirements, work-in-process inventory, material handling, inventory storage facilities, and throughput times [9]. To change to JIT work cells, the machines should have the flexibility to operate at different output rates.

To attain a flexible cycle time, a flexible layout is required. The two basic concepts used to design such layouts are [25]:

- Simplify the flows. Make material flow one way and get tooling in a cross flow,
- Minimize material handling. Avoid lifting by worker or by machine, and try to close up the space between machines.

One type of layout meeting both requirements is the U-line [39]. The U-shaped layout simplifies control, and allows gradual reduction of inventory and work-in-progress levels. There are advantages of the U-shape layout over the linear flow line. First, that it assists communication, since workers on a particular flow line are physically close to each other. The operator, for example, of the last machine in the flow line can easily tell the operator of the first machine about quality problem arising from the first operation and the appropriate action can be taken quickly. Second, workers have access to a number of machines, each worker being physically closer to more machines than they would be in a line, so workers are able to operate several machines at the same time. This facilitates the matching of production rates to demand rates.

Rearranging of the plant floor into cellular units or into flow lines reduces the distance a product has to move. As the unnecessary work-in-progress inventory disappears, units now spend more time being processed and having value added, and less time being shifted back and forth to wait in a queue and incur more cost.

Pull systems

A pull system is an information system that harmoniously controls the production and withdrawal of the necessary products in the necessary quantities and at the necessary time in every step of the process. It is a production scheduling and inventory control technique.

Toyota calls this particular technique, kanban. Kanban can be in many forms such as a piece of paper, board, color-code containers, etc., that can be used as an authorization signal for manufacturing control. It normally carries information about part name and number, container capacity and preceding and succeeding processes.

This technique has dramatically reduced work-in-process inventory levels, rework and scrap quantities. It also prevents transmission of increased fluctuation of demand from one process to the preceding process. Thus, the production processes become more responsive to changes in market demand.

A pull system is a technique used to run a manufacturing process based on JIT philosophies. The basic idea of the pull system of production is that a unit produces only in response to a requirement from the next operation [9]. The completed parts remain at the point of manufacture until withdrawn by the subsequent process, thus providing a visible signal to halt production when parts are not needed. As shown in Figure 1, the items pass through the flow line from operation 1 to 2 to 3 and then to final operation 4. When there is demand for finished products produced by operation 4, operation 4 produces the products. When operation 4 runs out of its required components as a result of finished products being removed, a signal is sent to operation 3. Then operation 3 produces components for operation 4. The process is repeated all the way down through the manufacturing system.

As can be seen, the benefits of a pull system are as follows:

(1) a low in-process inventory,

(2) prevention of the transmission of amplified fluctuations of demand to or from one process to the preceding process, and

(3) greater sensitivity to changes in market demand.

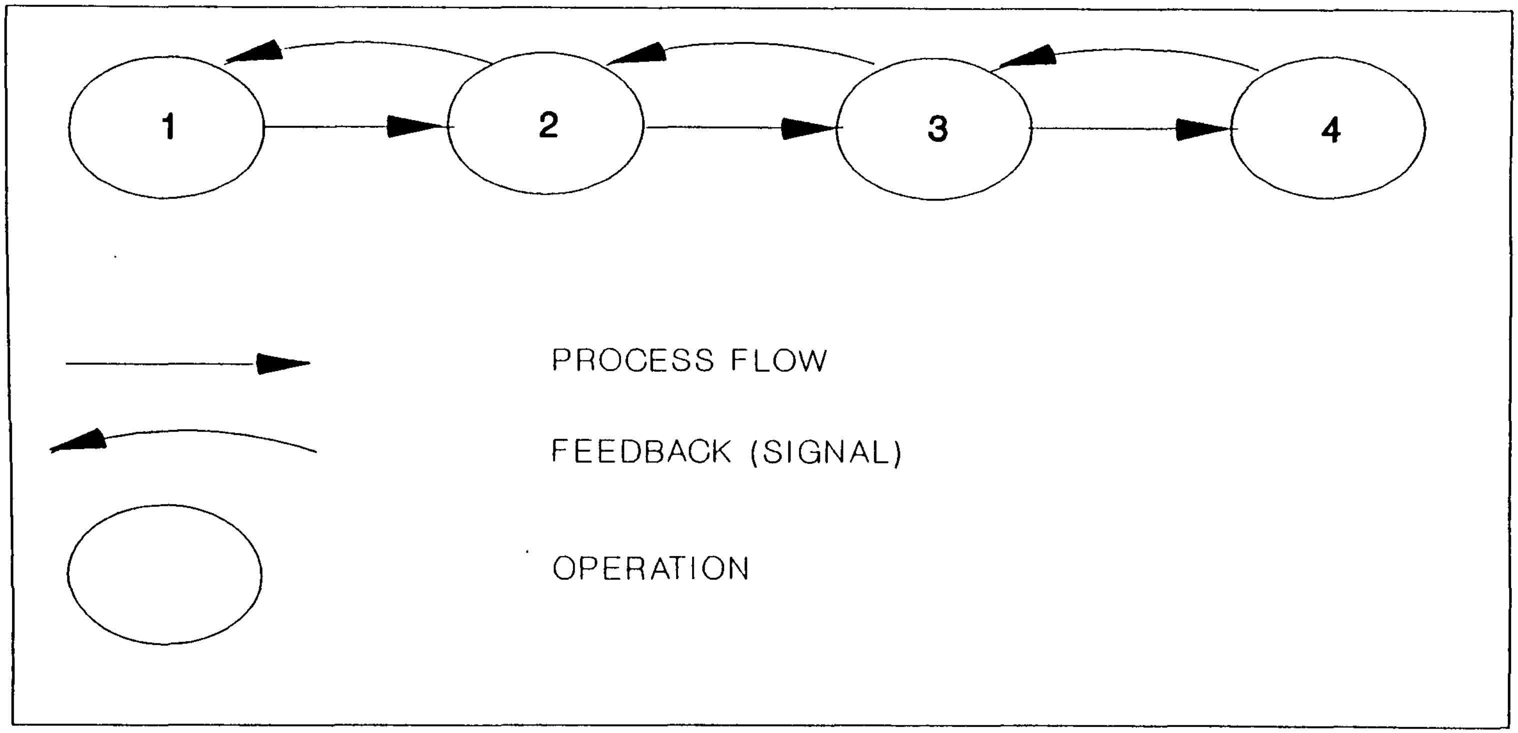

Figure 1. The concept of pull systems

Total preventive maintenance

In JIT manufacturing, inventories are reduced to a minimum. Manufacturing systems tend to incur costly shutdowns, particularly if there are unreliable machines or equipment in the manufacturing processes. When one machine breaks down, it affects the flow of the subsequent processes [46].

In conventional manufacturing systems, breakdowns do not place significant restrictions on production flow. Large buffers stocks are used to ensure that other machines are not starved of work in the event of a breakdown. In these situations the only machines affected are the bottleneck machines. These are machines running at full capacity, and a breakdown means that some production will inevitably be lost. For non-bottleneck machines, however, breakdown time can often be easily made up.

On the contrary, in JIT systems, buffer stocks have been so reduced that all machines are in a sense bottleneck machines and a breakdown will certainly reduce the effective utilization of equipment, and hence lower efficiency as well as increasing shortages, and lead times. In other words, breakdowns will remove some productive time from the machine and thereby lower both the effective utilization and the efficiency of the production line. Because there is little buffer stock, shortages result and the overall effect is an increase in manufacturing lead times.

To prevent this from happening, an implementation of a JIT system will have to include a total preventive maintenance program to ensure high process reliability. Total preventive maintenance (TPM) is a program of systematic inspection, detection, and prevention of failure in production and support equipment, a program that reduces delays, supports employee safety efforts, and ultimately reduces operating costs [22]. It can be separated into five parts, as follows:

1. Operator involvement,
2. Equipment selection,
3. Corrective maintenance,
4. Breakdown maintenance,
5. Record keeping.

Operator involvement is an important concept in TPM. It involves using operators as early warning systems, and as one aspect of preventive maintenance. The operators are responsible for increasing portions of routine preventive maintenance, such as cleaning and lubricating. The operators also become part of the decision-making process in the selection of new or replacement equipment. Finally, with the proper training and also gaining more experience, operators can handle more complex breakdown repair.

In addition to directly involving the operators in the selection process, equipment selection is based on lifecycle projections. Lifecycle projections consider maintenance costs and changeover costs in determining the overall cost of the machine.

Corrective maintenance involves minor repair usually of short-term planning that may happen between inspections, also yearly planned overhauls. It deals with adjusting and/or repairing an item which has ceased to meet an acceptable state.

Breakdown maintenance concerns failure resulting in the defect of an item. Operators must be taught first aid techniques and more complex techniques of breakdown maintenance later on.

The final component of total productive maintenance is record keeping. Operators are deeply involved in keeping records of problems, breakdowns, and costs. These records provide the basis for making purchasing decisions about new equipment.

Total quality control

The JIT philosophy is supported by a total quality control (TQC) program. TQC is a program that concentrates on eliminating defects. TQC is concerned with not only removing existing defects but also preventing defects before they occur. In just-in-time systems, a manufacturer will not carry excess inventory to reduce the consequences of defective parts. This forces the manufacturer to solve quality problems before the process can continue.

A TQC program does not use inspection to ensure the quality of parts but rather it shifts the responsibility for quality to the makers of the parts. This puts an emphasis on prevention and on the implementation of a good process control system.

Employee involvement

Employee involvement is the source of most of the really valuable ideas and suggestions of improvement in every area mentioned above. It is especially critical in terms of quality, productivity, and design.

Employee involvement requires that problem-solving work groups be established, along with a steering committee to guide their efforts. Work groups are trained in effective problem-solving techniques and in working effectively as a group. The steering committee regularly reviews the progress of the groups as they continuously identify, prioritize, select, and resolve problems. Once initial implementation activities are completed, the program focuses on employee involvement to constantly apply the JIT philosophy of waste elimination in the work environment.

An Overview of Inventory Acquisition

The objective of the purchasing function is to buy materials and services of the right quality, in the right quantity, at the right price, from the right source, and at the right time [43]. The following section will briefly describe the traditional paper-based, many-supplier purchasing approach and the more recent JIT purchasing approach.

Pre-JIT purchasing

In traditional purchasing systems, the required parts are ordered in large batch sizes within periods of time which may be determined by using an Economic Order Quantity (EOQ), Economic Order Point system. Multiple suppliers are selected and given short-term contracts. The selection of suppliers is based mainly on product price with secondary consideration given to product quality and delivery performance. The relationship between buyer and seller is adversarial in nature and is not generally characterized by cooperation. The suppliers are required to follow the production design provided by the buyer; a design that usually has not received any input from the supplier nor has considered any possible production difficulties of the supplier which could result in higher overall final product cost and lower product quality.

Due to multiple sources of supply, formal purchasing information systems include documents such as purchase requisitions, purchase orders, vendor invoices, and receiving reports. Controls and procedures are designed to process these documents which adds to the cost and time needed to purchase supplies. In addition, since purchases are made in large batches, large inventories must be kept which also increases the total cost of materials.

JIT purchasing

A just-in-time system is not only concerned with inventory control in a production setting, but also encompasses the purchasing function. In fact, JIT purchasing can be implemented independently of JIT production, but the concept of just-in-time in purchasing is similar to the just-in-time philosophy applied in manufacturing. Just-in-time purchasing is based on the continuing elimination of waste and inefficiencies. Waste is defined as anything that does not add value to the inventory, such as document processing (purchase orders, receiving reports, invoices, etc.), incoming inspections, material handling, and transportation. However, some of those activities are perceived as a necessary methodology used to control material flow between manufacturers and suppliers [2].

Under a just-in-time system, material will be purchased only when needed in a small quantity of high quality items. In order to implement just-in-time purchasing, it is important to enhance the relationship between the buyer and its suppliers. The relationship should be mutually beneficial and the buyer will have a fewer number of highly reliable suppliers [3]. The suppliers may participate in the design of the applicable part and may have access to the buyer's production schedule. Ansiri [1] advocates that fewer suppliers offer the following advantages:

- A minimum investment of resources such as buyers' and engineers' time,
- Consistent quality, because when buyers deal with fewer suppliers and involve them in the early stages of product design, suppliers can provide products consistently high in quality,
- Lower costs, because overall volume of items purchased from any one supplier is higher,
- Special attention from suppliers, since buyers represent large accounts,
- Minimal amounts spent by suppliers on tooling,

- Easily scheduled deliveries since all orders are placed with one supplier,
- Long-term relationships which encourage supplier loyalty and reduce the risk of an interrupted supply of parts to the buyer's plant.

The dominant criteria for selecting a supplier are product quality and delivery performance. A fair price is established in a long-term contract and, preferably, the supplier locates close to the buyer. The evaluation of quality can be done by keeping track of pertinent supplier information, such as: deviations from product specifications or the percentage of rejections. A method used to evaluate delivery performance can involve checking on-time deliveries or service responses.

Actually, a nearby supplier location is not essential as long as the supplier can perform satisfactorily in the categories mentioned above. If the supplier is not located nearby, vendor warehouses or plants may have to be relocated or the buyer may use company owned and operated vehicles or use a freight consolidation company. From the buyer view point, the first scheme might be considered if there is a close relationship between the buyer and supplier and the product quantity sold to the buyer is economically feasible. The second scheme is a practical one. For example, a company uses its own trucks and the truck drivers make routine pick-ups of required piece parts from suppliers within a certain area. The freight consolidation scheme involves a public carrier who might service a variety of vendors from the same truck load.

With just-in-time delivery, parts and materials are delivered to a dock adjacent to where the parts are needed and then these parts will be moved directly to the point-of-use in the plant. In other words, the parts are not moved to an intermediate warehouse or storage location. In some cases the deliveries are made right to the factory floor close to where the parts are needed in the operation. In both situations a quality inspection and physical count are not performed. It is assumed from the actual production schedule that a specified number of pieces were received from the supplier. Because the buyer and the suppliers work closely together with problems that arise on both sides of the manufacturing process, duplication of the inspection procedure by the buyer can be eliminated.

With more frequent deliveries of supplies, the amount of paperwork will be inevitably high. One way to reduce the paperwork is the use of a pull system or Kanban system. The pull system concept is introduced between a buyer and supplier and is similar to the approach applied to control information on the factory floor in a manufacturing process. As explained in the previous section on JIT production, Kanban can be in any form and is used to signal deliveries of the type and number of units needed. For example, Newman foundries uses its own rail tracks to deliver aluminum castings in standard containers with kanban cards attached. Deliveries are made to the Chevrolet transmission division once or twice a day and no paper documentation is used. Newman was one of the first suppliers to deliver to GM in this manner.

Electronic data interchange (EDI) refers to a computer-to-computer transmission of business documents. EDI is used to reduce clerical errors, lower transaction processing costs, enhance flexibility, and to provide for faster and better communication between buyer and seller. In an EDI system, the computer system transmits the purchase schedule or, alternately, makes the schedule electronically available for vendor inquiry. By using the computer interface, payment of the invoice may be done by using electronic funds transfer (EFT) which was one of the first applications of EDI. In some situations, the vendor does not submit an invoice. The buyer assumes that a certain number of parts have been delivered in a given time period. Since the price has been agreed upon in the long-term contract, no human action may be necessary to complete the transaction. Furthermore, if EDI is combined with automatic funds transfer, the purchasing function can be made entirely paperless [48].

CHAPTER III. THE AHP MODEL

Explanation of the Model

The Analytic Hierarchy Process (AHP) developed by Thomas Saaty (1977) is a systematic approach used to determine the relative importance of a set of activities or criteria. AHP is simple to follow and use but can handle complex or multiple criteria problems. It is a functional tool for solving relatively complex, unstructured problems for which ranking of alternatives is not possible directly. Saaty's model is based on three steps which are discussed in the following paragraphs.

The AHP methodology

The first step in using the AHP model is to decompose the criteria or factors of concern into a hierarchical structure. Structuring a hierarchy is the dominant feature of AHP. The hierarchy generates an easy way to manage multi-criteria problems by dealing with smaller subproblems.

An example of a hierarchy is illustrated in Figure 2. The top of the hierarchy represents the overall objective. The second level addresses the criteria that relate to the

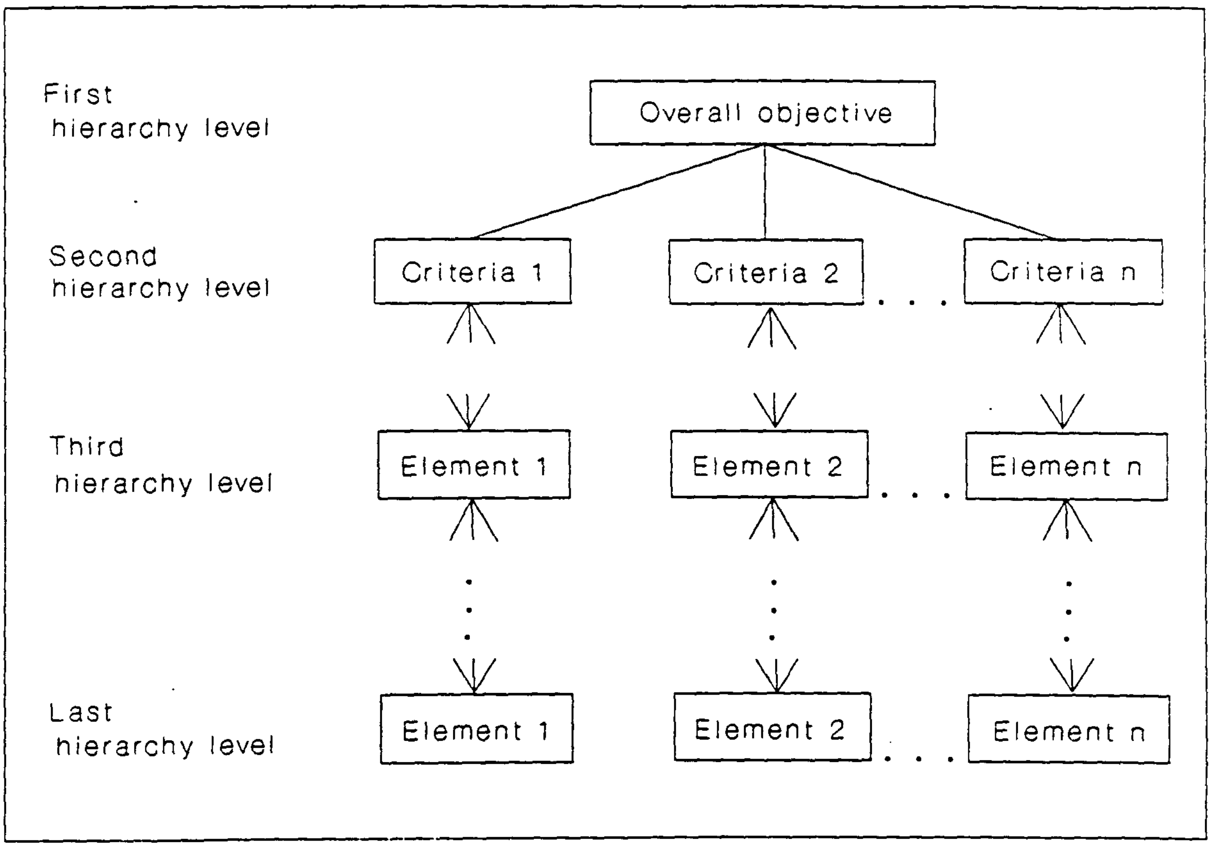

Figure 2. The hierarchial structure

objective. The third level contains the attributes of the criteria, and so on.

There are two rules to be considered in order to set up each level of the hierarchy. The elements in each level should have similar properties or magnitudes and they should relate to the elements of the adjacent level.

The number of the levels is not restricted. The number depends on the complexity of the individual problem, however, the number of elements in each level is preferably not more than nine [40].

After decomposing the problem into a hierarchical structure, the second major step involves a pairwise comparison method to extract the relative importance of each element with respect to each element in the upper adjacent level. This provides a quantitative judgment for prioritizing the criteria. This step can be fulfilled by asking the respondents to make quality judgments in a pairwise manner. Then a matrix of pairwise comparisons is constructed as follows.

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix}_{n * n} \quad (1)$$

The value of the cell (i,j) in the matrix is the relative importance of criterion i over criterion j. The matrix is a reciprocal matrix, hence

$$a_{ij} = \frac{1}{a_{ji}} \;; i,j = 1,2,\ldots,n \quad (2)$$

whereas $a_{ij} = \frac{w_i}{w_j}$

where $W = (w_1, w_2, \ldots, w_n)^T$ is the vector of actual relative importance and n is the number of elements. In matrix algebra W and n are called the eigen vector and eigen value respectively.

In order to develop pairwise comparison matrices for the various hierarchic levels, the scale of importance based on a physical experiment by Miller [35] as shown in Table 1 is used.

Table 1. The scale of importance (Saaty, 1980, 54)

Importance	Definition	Explanation
1	Equal importance	Two attributes contribute identically to the objective.
3	Weak dominance	Experience or judgment slightly favors one attribute over another.
5	Strong dominance	Experience or judgment strongly favors one attribute over another.
7	Demonstrated dominance	An attribute's dominance is demonstrated in practice.
9	Absolute dominance	The evidence favoring an attribute over another is affirmed to the highest possible order.
2,4,6,8	Intermediate values	Further subdivision or compromise is needed.

In the <u>third</u> major step, the vector of actual relative importance is calculated by multiplying vector A by vector W which produces nW as follow:

$$A*W = n*W \tag{3}$$

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \qquad (4)$$

Nevertheless, in the general case, there doesn't exist an exact ratio of w_i/w_j. In other words, there may not be consistency from one judgment to another related judgment. For example, if $a_{12} = 2$ and $a_{23} = 4$, a_{13} should be equal to 8 to maintain the consistency in this series of judgments.

However, because humans do not make judgments in a strictly linear and consistent manner, it is a common phenomenon for there not to be perfect consistency in a series of judgments. Notwithstanding a consistency problem, the value of a cell in the matrix A can be approximated from other judgments made by the decision maker. Hence, equation (3) becomes

$$A*W = \lambda_{max}*W \qquad (5)$$

where $\lambda_{max} \geq n$

The value of the λ_{max} indicates the consistency of the vector of relative importance. It implies that the closer the λ_{max} is to n, the more consistent the vector of relative importance. This property leads to the construction of the consistency index (CI) as

$$CI = \frac{\lambda_{max}-n}{n-1} \quad (7)$$

and of the consistency ratio (C.R.) as

$$CR = \frac{CI}{RI} \quad (8)$$

The random index (RI) is the consistency index of a randomly generated weight. The numerical values of the RI are shown in Table 2. The consistency ratio should be 10 percent or less for the overall model to be satisfactory [40]. Otherwise it is recommended that the vector of relative importance of that matrix be reobserved.

Table 2. Values of the random index (Saaty, 1980, 21)

n	R.I.	n	R.I.
1	0.00	9	1.45
2	0.00	10	1.49
3	0.58	11	1.51
4	0.90	12	1.48
5	1.12	13	1.56
6	1.24	14	1.57
7	1.32	15	1.59
8	1.41		

Previous Applications of AHP

AHP has been applied to many different decision making problems. Muralidhar, Santhanam, and Wilson [38] used AHP for information system (IS) project selection. They stated that

> AHP satisfies the requirements of a good IS project selection methodology. It allows factors to be satisfied in a multi-criteria setting, provides the ability to express the relative importance of the multiple criteria being considered, and uses pairwise comparisons in extracting information.

He also claimed that the single criteria approach used by existing methodologies failed to provide these capability and the AHP methodology was an improvement over some existing methodologies such as cost/benefit analysis, and ranking and scoring. He further stated

> ... the characteristics of the IS project selection problem dictates that the methodology used must have three capabilities: to handle multiple criteria, to evaluate projects on tangible and intangible criteria, and to establish the relative importance of each criteria. Furthermore, it must be flexible and easy to use, so that current dissatisfaction regarding IS project selection methodologies can be reduced. Existing methodology fail to satisfy one or more of these factors.

Thus, for the comparison purposes, the ranking methodology was applied to this study. The result shows that the order from the ranking methodology was significantly different from the order provided by the AHP method. They concluded that because the ranking method failed to considered the relative importance of criteria, consequently applying the ranking approach without considering the relative importance of the criteria may result in the selection of projects that were not in congruence with organizational objectives. They stated that AHP was well suited to address the issues in IS project selection and was an improvement over existing methodologies.

Harper [18] employed the AHP to create judgment models of a sample of Big Eight public accounting firms' EDP (Electronic Data Processing) Auditors' evaluations of internal control in local area networks. He indicated that AHP was appropriate for his study because it allowed a wide number of cues to be considered, and the hierarchial structuring of the cues into categories allowed a reduction in the tasks required of subjects. He decomposed his problem into 2 levels of hierarchy by comparing categories in the first level, and by comparing controls within each category in the secondary level of hierarchy. He claimed that without the use of AHP in categorizing the attributes of concern into a hierarchy fashion, an incomprehensible total of 136 pairwise comparisons would have been required instead of making five sets of comparisons or 34 total pairwise comparisons. From the result of his study, the consistency ratio showed that some respondents did not answer the questionnaires consistently. Therefore, consistency of AHP responses were examined for a possible impact on consensus among EDP auditors' judgment models. Using Saaty's .10 "acceptability" threshold, full judgment model inter-rater correlations among the 27 subjects with CR $\leq$ 0.10 were compared with the correlation among the 24 subjects with CR > 0.10. The result showed that the responses from these two groups were significantly different.

In this study, he also asked the respondents to select the two controls they felt were most important. The purpose was to compare the two controls selected with the controls raking high in the relative importance by using the AHP judgment model. This methodology based on the assumption that: 1) if the AHP model is valid, then this will investigate the respondent insight. 2) if the respondent assumed to be capable of choosing the most important controls from a list, then this will investigate the validity of AHP model perceived weight. From his data analysis, it was clear that most subjects were able to choose the controls that were relatively high in importance by using the AHP model, but not the two exact controls that prior pairwise comparison indicated were most important. This became an open issue whether these reported results indicate imperfect insight of the respondent or whether the AHP process accurately reflects their judgment models.

Lin, Mock, and Wright [30] identified the usefulness of the AHP as an aid in planning the nature and extent of audit procedures. The research objective was to examine features of AHP as a tool to evaluate audit evidence and program planning in the accounts receivable audit area. They explained the reason for using the AHP in their research was because AHP offered the potential for greater rigor and efficiency when compared to traditional heuristic evidence evaluation procedures. The authors further expressed that the AHP was easy to understand, to apply and required limited decision maker time. However, they thought the AHP tended to give slightly higher decision variability due to the subjects' lack of familiarility with the AHP methodology. The limitation of AHP model from the researchers point of view was that the more the attributes or criteria included in the problem, the more the number of the paired comparisons. For this limitation, they considered that even though the actual audit decisions might entail the consideration of numerous factors, one can reduce the number of criteria and procedures considered to a critical, feasible set for a problem. This might give rise to further empirical research to assess whether this limitation of the AHP was a serious problem in practice or not. Finally, the authors suggested the AHP might be used in other audit areas- such as the evaluation of different audit programs, internal control evaluation procedures, statistical sampling techniques, analytical review techniques.

Lusk [32] introduces the AHP as a structured and consistent means to develop managerially relevant information regarding alternative selection for complex decision in the hospital capital decision alternatives situation. The criteria used in evaluating seven proposals regarding the construction of a cardiology care unit (CCU) concerning promoting the economic growth of the institution. There were seven alternatives to be evaluated on each of the criterion. The purpose of this paper was to report how the eigenvalue priority assignment model was used to develop the information which was presented to the hospital planning committee. The result from this research supported the author to believe that the eigenvalue priority judgment model possessed the good aspects for complex decision making problems.

Arguments Against the AHP Model

The possible difficulty of using AHP or misunderstanding of AHP capability gathering from the user experience are as follows:

Lin et al. (1984) pointed out that the number of pairwise comparisons grew extensively as additional attributes and or alternatives are incorporated into an AHP model. As Saaty (1980) stated, the strength of AHP was the structuring of attributes or alternatives. Therefore, categorizing multiple attributes into meaningful components can mitigate the validity of this problem.

Dyer [7] said that the AHP was flawed as a procedure for ranking alternatives in that the rankings were arbitrary. His paper brought in the operational difficult areas in using AHP, and then focused on the ranking procedure of hierarchic composition. He came up with the way to correct the flaw of the AHP by applying a theory called "multiattribute utility theory (MAUT). Nevertheless, Saaty pointed out that the interval scale of utility theory could not be used throughout a decision process. He explained that this was because the product of two interval scale numbers from the same or from different interval scales did not belong to an interval scale. Thus he refused to employ the MAUT theory.

Further, Dyer questioned the ambiguity that is inherent in all preference elicitation methods as "How much better is A_i than A_j on a criterion? His appropriate response would be relative to what?" The point is what is the reference point?. Harker and Vargas [17] argued that according to the AHP methodologies, the questions used in this method were not as Dyer described. Secondly, the definition of the criterion always involved a point of reference. "The AHP does not take a fixed reference point but, rather, treats all alternatives as reference points in order to minimize any bias which may be introduced through the selection of a single focus for the comparisons", Harker and Vargas stated.

Dyer also objected to the 1-9 scale. He presented an example where a decision maker preferred A three times more than B and B five times more than C, which would imply that A be 15 times more preferred than C. However, with a scale limited by 9, this consistent judgment was not permitted. For this problem, Harker and Vargas proved that 1-9 scale was valid for this case, since there was little difference between 1-15 scale and 1-9 scale. Thus the use of 1-9 scale did not affect the AHP theory.

CHAPTER IV. THE EXPERIMENT

Project Design

Generally, the reason that manufacturers change a traditional manufacturing system is to increase manufacturing efficiency and effectiveness. From the literature on JIT systems, there are several techniques for implementing just-in-time manufacturing systems. Typically, these are setup time reduction, group technology, uniform plant load, pull systems, total preventive maintenance, and just-in-time purchasing.

Following the framework of the AHP model, a hierarchy is constructed to represent this concept and is shown in Figure 3. The resultant three level hierarchical model is of the following configuration:

Level 1: Goal - Increasing manufacturing efficiency and effectiveness.

Level 2: Objective
- Reducing inventory.
- Improving quality.
- Increasing productivity.

Level 3: JIT techniques
- Setup time reduction.
- Total preventive maintenance.

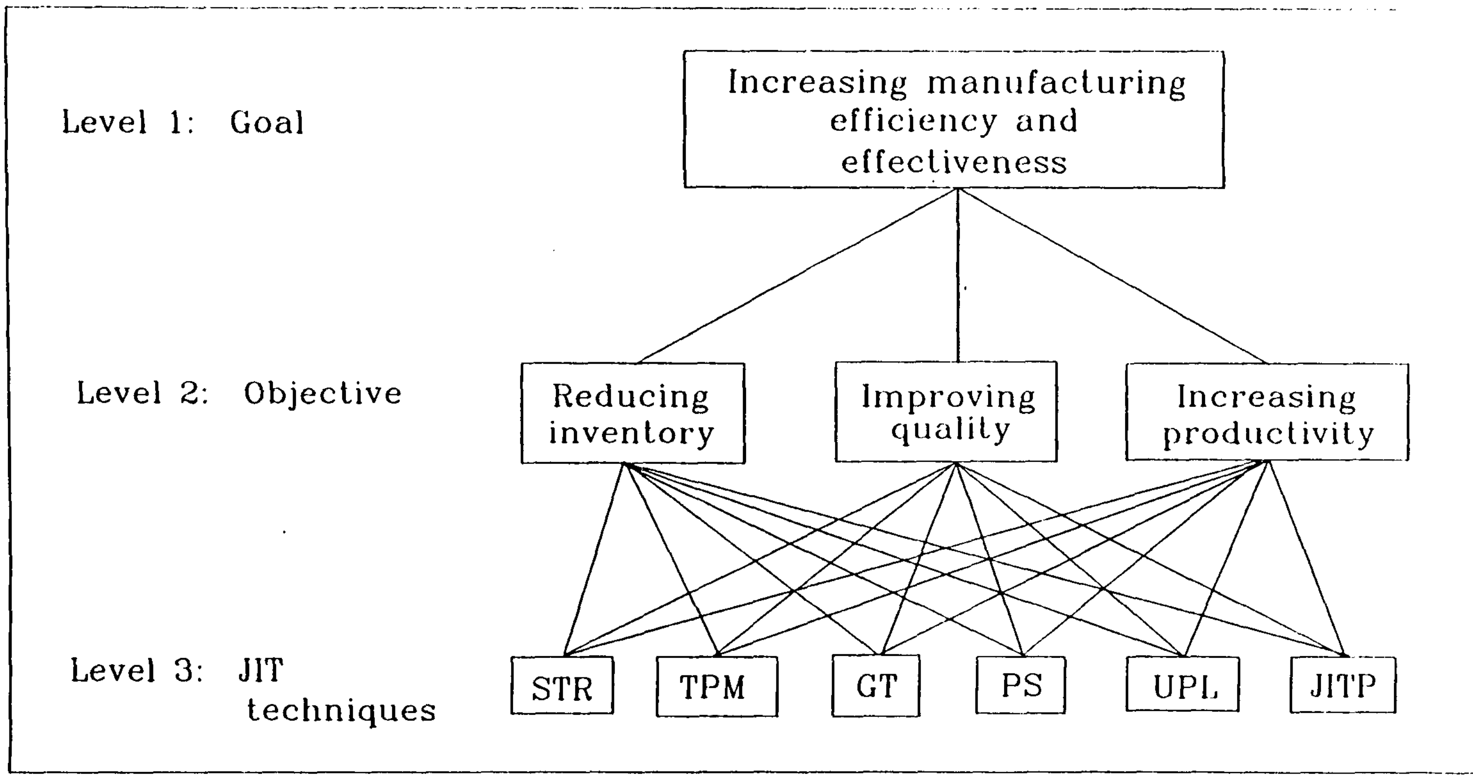

Figure 3. The designed hierarchical structure

- Group technology.
- Pull systems.
- Uniform plant load.
- JIT purchasing.

The Survey

The second stage of this research is the distribution of a mailed questionnaire. The objective of this survey is to obtain information from manufacturing managers concerning JIT techniques used in JIT systems. This information will be used to determine the relative importance of the selected JIT implementation techniques in their respective roles of reducing inventory, improving quality , and increasing productivity. In addition, the relative importance of inventory reduction, quality improvement, and productivity increase is assessed with respect to the overall goal of increasing manufacturing efficiency and effectiveness.

The survey method was chosen as a means to economically solicit data from manufacturing managers who might be involved with just-in-time manufacturing systems. Four-hundred questionnaires were sent out equally to five different types of manufacturing firms where just-in-time systems are expected to be in use. The types of firms selected included motor vehicles and equipment, electronic component and accessories, electronic computers, industrial and commercial machinery and computer equipment, and electrical industrial apparatus. A copy of the questionnaire is included in Appendix A.

The sample for each of the five types of manufacturing firms was based on number of employees (preferably more than 100). A random sampling procedure was not used. The researcher attempted to select firms in each category in geographic areas of the U.S. where the preselected manufacturing types of firms are concentrated. The addresses of the manufacturing firms were obtained through California Manufacturers Register Handbook [6], Directory of Corporate Affiliations Handbook [7] and Million Dollar Directory [42].

The survey instrument consisted of 2 sections. Section 1 required respondents to contribute background information about themselves and about their firm. This information is compiled to provide a profile of the sample industry characteristics. If the firm at that location did not operate under a just-in-time system, the instructions asked the respondent to explain why his/her plant had not implemented a just-in-time system. After explaining why, the respondent was requested to stop at that question and return the questionnaire. Section 2 required the respondents to evaluate the relative importance of the objectives of implementing just-in-time systems, and the relative importance of just-in-time implementation techniques with regard to each of those objectives by using the AHP pairwise comparison method.

Data Analysis

Forty-seven manufacturing firm responses (12%) were received. Thirty-three responses have implemented JIT systems. However, 28 were useable (referred to the overall consistency ratio was less than or equal to .1): 4 from computer industries, 4 from machinery industries, 7 from automotive industries, and 13 from electronic device industries. Fourteen respondents indicated that they did not have any JIT systems in their manufacturing firms. Reasons of not implementing JIT systems are illustrated in Table 3. Roughly 17 percent did not implement any aspect of JIT systems, and interestingly, half of those firms pointed out that they had not implemented JIT because of lack of upper management support.

For the data analysis; the software package, "Expert Choice," was used to calculate the principal eigen vector solution, and the software package "Statistix" was used to do the statistical analysis. The software features for those two packages are described in Appendix B.

Table 4 provides the descriptive statistics. Most of the respondents were manufacturing, operation, or production managers/ vice presidents with an average of 5.5 years of

Table 3. Reasons of not implementing JIT systems in the manufacturing process

1. In the process of implement MRP system, but within the 18 months JIT systems will be introduced in the manufacturing process.
2. In the process of implement MRP II system, and hopefully will implement JIT systems in the year of 1993.
3. Lack of long term planning and visibility.
4. In the research and development period. Most of their contracts are for very small quantities.
5. Still in the initial states of TQM and not ready for JIT.
6. The customer demands (lead time, vary quantities) and process problems prohibit at this time
7. Upper management has not given the priority.
8. Attempt to have JIT systems in manufacturing process but still have concealed limited factors to make JIT workforces at the present time.
9. Make to order environment with 100's of different configurations and 20000 part numbers. Electronic environment with numerous changes daily, lack of on-line systems and has not been senior management objective.
10. Variations in the product mix.
11. The methods of material procurement do not support JIT systems. But having plan for implementing JIT within next two years.
12. Implementation scheduled for last quarter.
13. Lack of top management support.
14. Raw material are bought in bulk and released a needed. Do not buy any "component" parts to go into final assembly which would be better suited for JIT.

Table 4. Descriptive statistics

Variable	Mean	S.D.	Median	Minimum	Maximum
No. of years of personal experience with JIT systems	5.500	2.431	5.000	1.500	10.000
No. of years of JIT systems implemented in plant	3.893	2.229	3.750	1.000	10.000
No. of distinct product	19.750	52.520	5.000	1.000	210.000
No. of employee	465.500	553.900	300.000	60.000	2000.000
<u>Weight</u>					
Local inventory	0.228	0.212	0.115	0.061	0.769
Local production	0.549	0.212	0.644	0.104	0.798
Local quality	0.224	0.183	0.141	0.053	0.769
INV-STR	0.201	0.098	0.232	0.040	0.344
INV-TPM	0.146	0.113	0.094	0.034	0.413
INV-PS	0.162	0.115	0.155	0.025	0.404
INV-GT	0.148	0.133	0.105	0.003	0.595
INV-UPL	0.163	0.140	0.097	0.028	0.471
INV-JITP	0.181	0.128	0.150	0.028	0.510
QUA-STR	0.163	0.113	0.139	0.029	0.381
QUA-TPM	0.249	0.124	0.284	0.004	0.444
QUA-PS	0.155	0.138	0.09	0.250	0.442
QUA-GT	0.214	0.143	0.165	0.029	0.615
QUA-UPL	0.102	0.085	0.071	0.028	0.312
QUA-JITP	0.118	0.104	0.082	0.022	0.357
PRO-STR	0.224	0.093	0.259	0.031	0.347
PRO-TPM	0.206	0.105	0.217	0.027	0.396
PRO-PS	0.155	0.134	0.134	0.032	0.524
PRO-GT	0.186	0.140	0.154	0.040	0.543
PRO-UPL	0.147	0.102	0.115	0.028	0.348
PRO-JITP	0.081	0.053	0.082	0.022	0.209
Global STR	0.185	0.086	0.172	0.047	0.352
Global TPM	0.280	0.096	0.227	0.043	0.348
Global PS	0.157	0.120	0.130	0.029	0.444
Global GT	0.190	0.129	0.166	0.028	0.559
Global UPL	0.136	0.095	0.100	0.028	0.330
Global JITP	0.125	0.083	0.088	0.026	0.312
<u>Consistency ratio</u>					
overall	0.063	0.025	0.070	0.000	0.090
Relative importance of objectives	0.047	0.032	0.046	0.000	0.093
Relative importance of JIT techniques					
with respect to inventory reduction	0.072	0.039	0.074	0.003	0.152
with respect to productivity increasing	0.087	0.128	0.067	0.001	0.720
with respect to quality improvement	0.112	0.175	0.066	0.000	0.860

Note: INV => Inventory reduction objective
QUA => Quality improvement objective
PRO => Production increasing objective
STR => Setup time reduction
TPM => Total preventive maintenance
PS => Pull systems
GT => Group technology
UPL => Uniform plant load
JITP => Just-in-time purchasing

personal experience with JIT systems. JIT systems have been in operation for 4 years on average in the sample group plants. The number of employees in each plant varies from 60, which could be considered a small plant, to 2000, which could be considered a large plant.

Out of the 28 plants, there are only 5 plants that have less than 100 employees, 21 plants that have the employees between 100 and 750, and 2 plants that have employee more than 1200 as shown in the frequency distributions of the number of employees in Appendix C.

As can be seen from the descriptive statistics table, the main purpose that JIT has been adopted in these manufacturing firm is to increase productivity in the production process. Total preventive maintenance is perceived to be the most important technique in implementing JIT systems, then group technology, set up time reduction, pull systems, uniform plant load, and JIT purchasing (Figure 4). In addition to this, when pilot projects are considered under the increasing productivity objective, the three most important pilot projects for this objective are set up time reduction , total preventive maintenance, and group technology (Figure 5). Whereas, the three most important

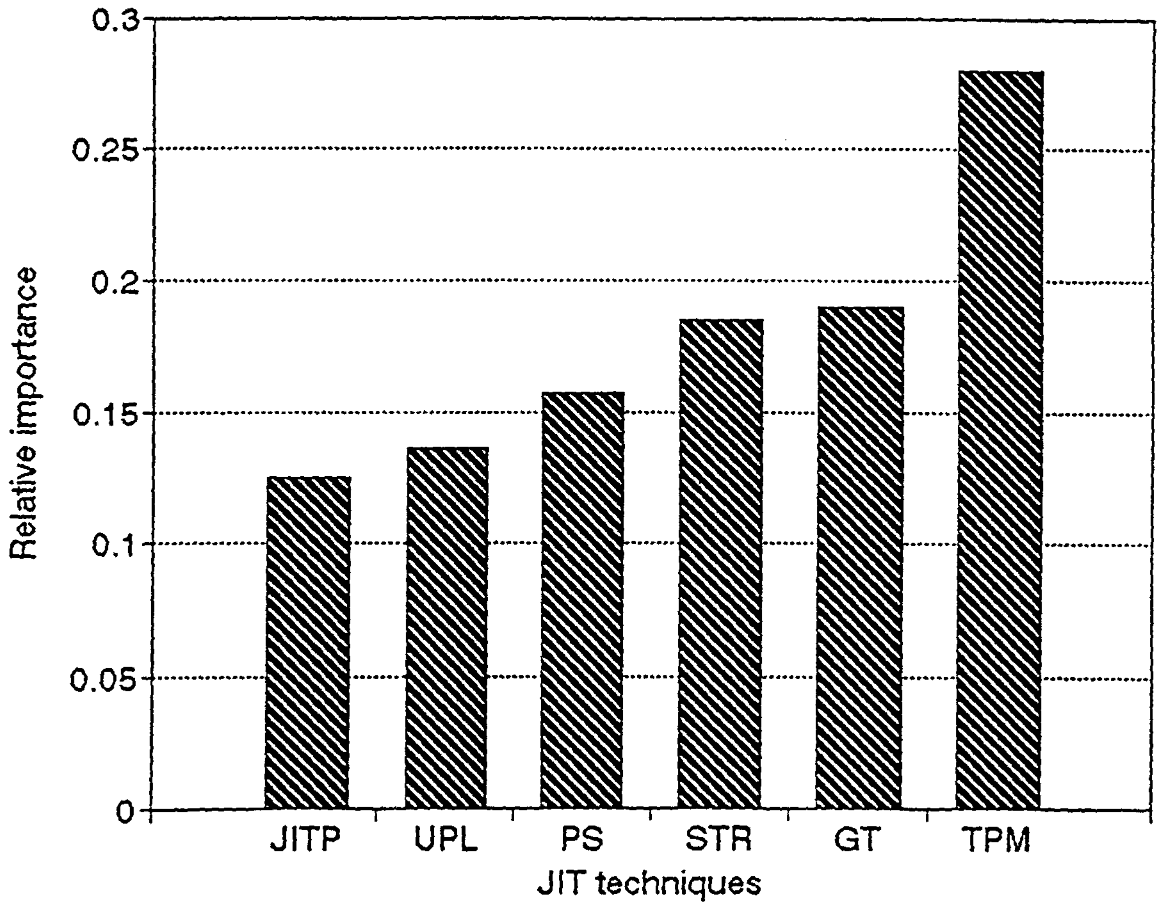

Figure 4. The relative importance of JIT techniques with respect to the goal of increasing manufacturing efficiency and effectiveness

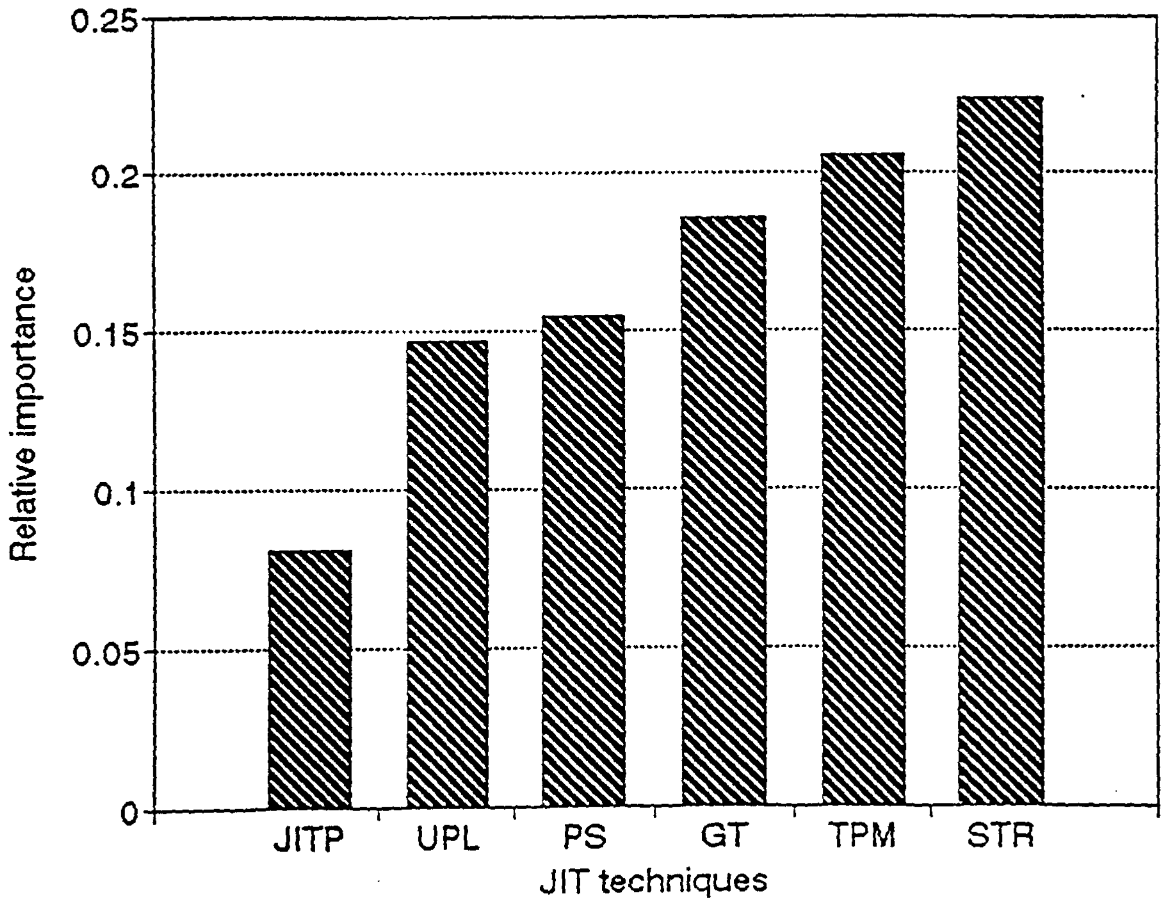

Figure 5. The relative importance of JIT techniques with respect to the objective of increasing productivity

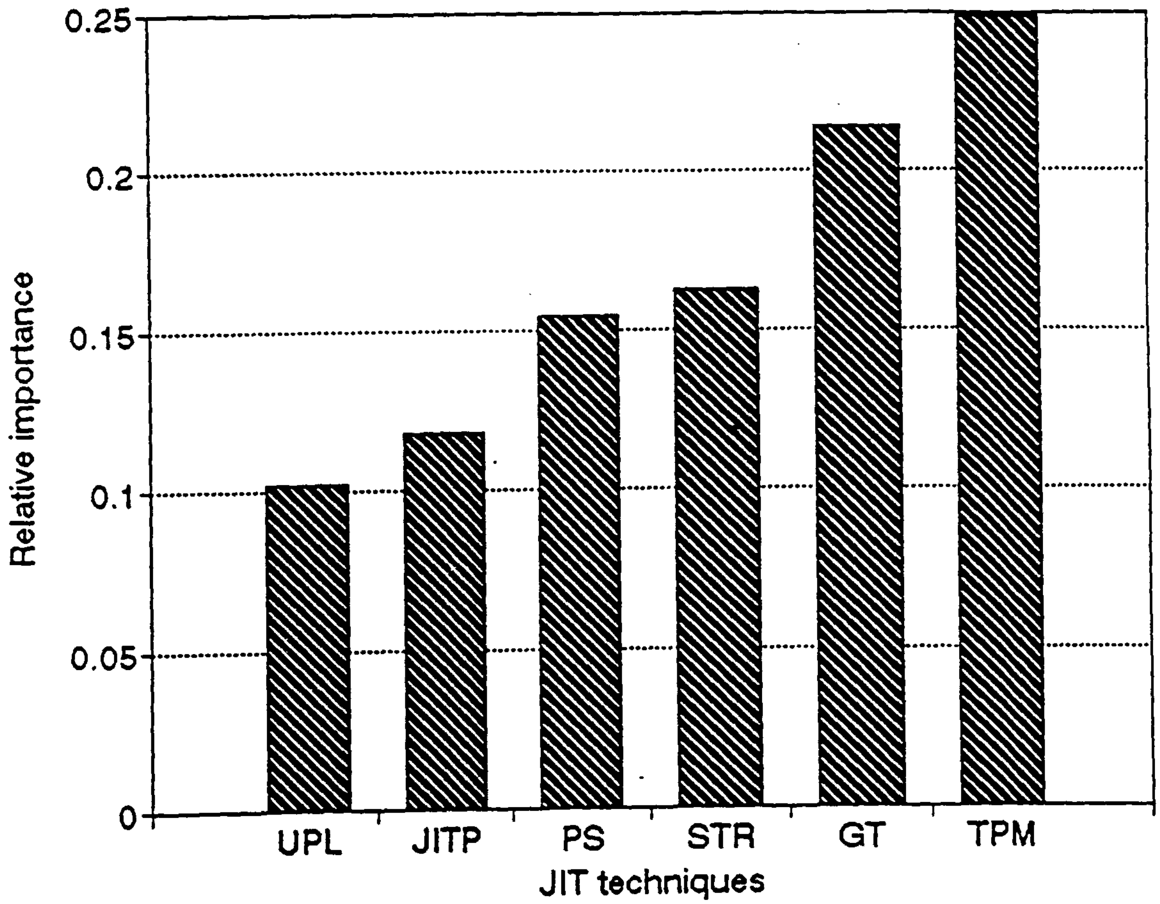

Figure 6. The relative importance of JIT techniques with respect to the objective of improving quality

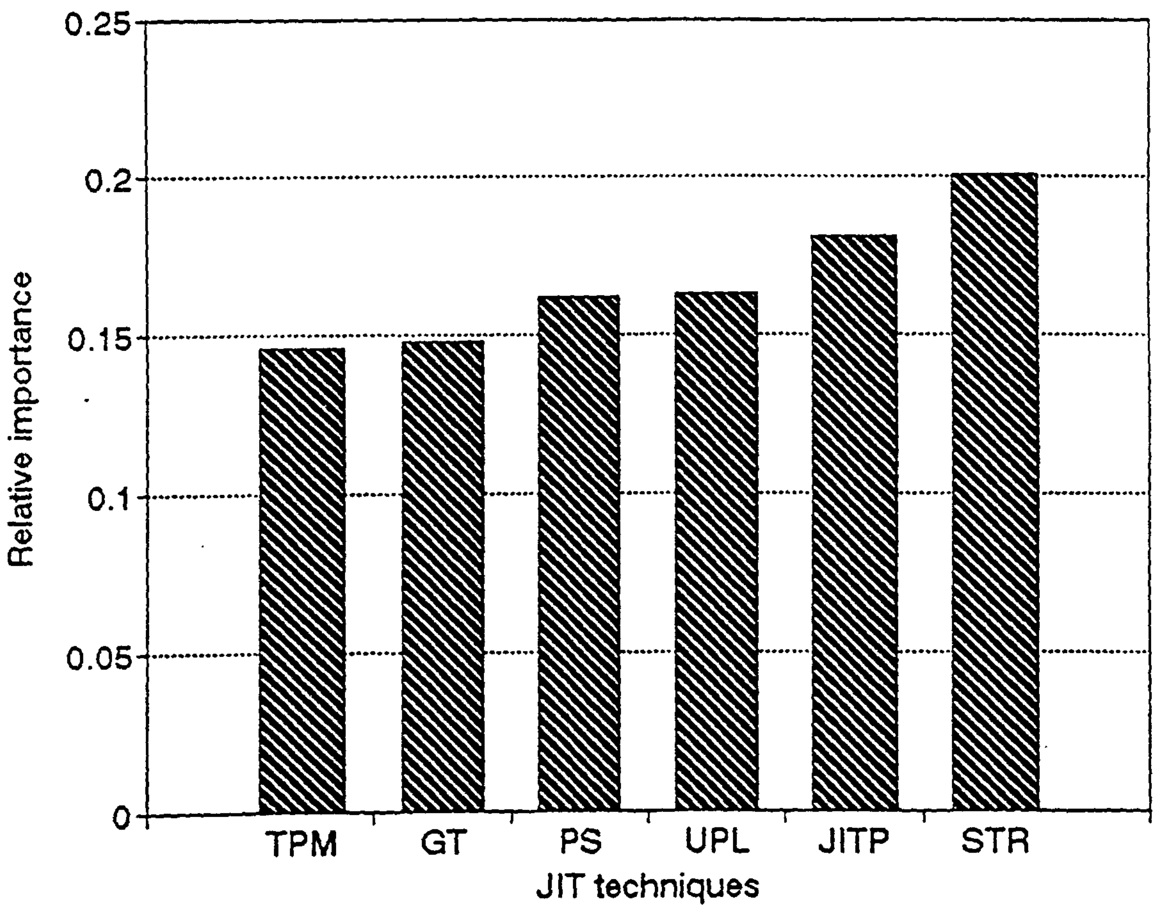

Figure 7. The relative importance of JIT techniques with respect to the objective of reducing inventory

pilot projects for the quality improvement objective are total preventive maintenance, group technology, and set up time reduction (Figure 6). The three most important pilot projects for the inventory reduction are setup time reduction, JIT purchasing, and uniform plant load (Figure 7).

The consistency ratio of the respondents in replying the questionnaires are .06 for the overall consistency ratio, and .05 for the relative importance of objective consistency ratio. Whereas the consistency ratio for the relative importance of JIT techniques under production increasing, quality improvement, and inventory reduction are .09, .10 and .07 respectively. These perceive that the respondents have consistent response to the AHP model. However, there is no consensus among the respondents on weighing the 9 criteria, as indicated by high standard deviation.

Accordingly, the one way anova was used to investigate whether

1) the objective in implementing JIT systems are all at the same level of importance with respect of the goal of implementing JIT systems
2) the six JIT techniques are all at the same level of importance with respect to the goal of implementing JIT systems

3) the six JIT techniques are all equally important with respect to a particular JIT objective.
4) each JIT technique is equally important with respect to the JIT systems.

Table 5 presents one way anova analysis. At the α level of significance, using p values to reject Ho for any $P < \alpha$, and not to reject H_o otherwise. $\alpha = .05$ was chosen. The summaries of results based on 28 plants responses are shown in table 6.

Accordingly, the two samples t-test was used to investigate

1) which objectives in implementing JIT systems are significantly different
2) with respect to the goal, which JIT techniques are significantly different.
3) with respect to the production increasing objective, which JIT techniques are significantly different.
4) with respect to the quality improvement objective, which JIT techniques are significantly different.

Table 7 presents two tailed t-test analysis. The summaries of results are shown in Table 8. Finally, the Spearman rank correlation was calculated, as shown in Table 9. These results imply that the respondents who have more

Table 5. Analysis of variance

Test	Source	DF	SS	MS	F	P
Objective	Between	2	1.945	0.973	23.62	0.0000 *
	Within	81	3.336	0.041		
	Total	8	5.281			
STR, TPM, GT	Between	5	0.149	0.030	2.80	0.0187 *
PS, UPL, JITP	Within	162	1.717	0.011		
	Total	167	1.866			
STR, TPM, GT,	Between	4	0.089	0.022	1.97	0.1019
PS, UPL	Within	135	1.529	0.011		
	Total	139	1.618			
PRO-STR, PRO-TPM	Between	5	0.364	0.073	6.19	0.0000 *
PRO-GT, PRO-PS	Within	162	1.907	0.012		
PRO-UPL, PRO-JITP	Total	167	2.271			
PRO-TPM, PRO-STR,	Between	4	0.120	0.030	2.21	0.0708
PRO-GT, PRO-PS,	Within	135	1.830	0.014		
PRO-UPL	Total	139	1.949			
QUA-STR, QUA-TPM	Between	5	0.440	0.088	6.15	0.0000
QUA-GT, QUA-PS	Within	162	2.319	0.014		
QUA-UPL, QUA-JITP	Total	167	2.759			
QUA-TPM,QUA-STR,	Between	2	0.105	0.052	3.22	0.0439
QUA-GT	Within	81	1.316	0.016		
	Total	83	1.421			
QUA-STR, QUA-PS,	Between	3	0.071	0.0237	1.90	0.1321
QUA-JITP, QUA-UPL	Within	108	1.348	0.0124		
	Total	111	1.420			
QUA-GT, QUA-STR,	Between	2	0.058	0.029	1.66	0.1939
QUA-PS	Within	81	1.417	0.017		
	Total	83	1.475			
INV-STR, INV-TPM,	Between	5	0.062	0.012	0.84	0.5259
INV-GT, INV-PS,	Within	162	2.400	0.015		
INV-UPL, INV-JITP	Total	167	2.462			
INV-STR, QUA-STR,	Between	2	0.054	0.027	2.61	0.0778
PRO-STR	Within	81	0.836	0.010		
	Total	83	0.890			
INV-TPM, QUA-TPM	Between	2	0.149	0.075	5.73	0.0049 *
PRO-TPM	Within	81	1.056	0.013		
	Total	83	1.206			
INV-GT, QUA-GT,	Between	2	0.063	0.031	1.63	0.2010
PRO-GT	Within	81	1.561	0.019		
	Total	83	1.623			
INV-PS, QUA-PS,	Between	2	0.001	0.001	0.03	0.9578
PRO-PS	Within	81	1.357	0.0168		
	Total	83	1.358			
INV-UPL, QUA-UPL,	Between	2	0.056	0.028	2.26	0.1091
PRO-UPL	Within	81	1.002	0.012		
	Total	83	1.058			
INV-JITP,	Between	2	0.142	0.071	7.05	0.0016
QUA-JITP,	Within	81	0.814	0.010		
PRO-JITP	Total	83	0.955			

Note: * Reject null hypothesis

Table 6. Results from analysis of variance

Test	Result
Objective of implementing JIT systems	At least two objectives are significantly different.
JIT techniques	
- with respect to the goal	No significant difference among five techniques. Those are UPL, PS, STR, GT, and TPM
- with respect to production increasing objective	No significant difference among five techniques. Those are UPL, PS, GT, TPM, and STR.
- with respect to quality improvement	No significant difference among four techniques. Those are UPL, JITP, PS, and STR.
- with respect to inventory reduction	No significant difference among six techniques.

Table 7. Two sample t-test

VARIABLES	T	DF	P
INV-OBJ V.S. QUA-OBJ	0.08	52.8	0.9374
INV-OBJ V.S. PRO-OBJ	-5.65	54.0	0.0000*
PRO-OBJ V.S. QUA-OBJ	6.14	52.8	0.0000*
JITP V.S UPL	-0.49	53.1	0.6265
JITP V.S. GT	-2.25	46.2	0.0296*
TPM V.S. GT	0.58	49.8	0.5630
JITP V.S. UPL	-0.49	53.1	0.6265
JITP V.S. GT	-2.25	46.2	0.0296
PRO-JITP V.S. PRO-UPL	-3.03	40.8	0.0043*
QUA-TPM V.S. QUA-GT	0.96	52.9	0.3395
QUA-TPM V.S. QUA-STR	2.71	53.5	0.0090*
QUA-GT V.S QUA-STR	1.49	51.2	0.1424
QUA-GT V.S QUA-JITP	2.88	49.3	0.0058*
PRO-TPM V.S. QUA-TPM	-1.38	52.6	0.1727
PRO-TPM V.S INV-TPM	2.07	53.8	0.0432*
QUA-TPM V.S. INV-TPM	3.25	53.5	0.0020*
INV-JITP V.S. QUA-JITP	2.03	51.8	0.0480*
QUA-JITP V.S. PRO-JITP	1.64	40.3	0.1097
INV-JITP V.S. PRO-JITP	3.78	36.1	0.0006*

Note: * Reject null hypothesis

Table 8. Results from two sample t-test

Test	Result
Objective of implementing JIT systems	Productivity increasing objective is significantly more important than the others.
JIT techniques - with respect to the goal	JITP is significantly less important than TPM, GT, and STR.
- with respect to production increasing objective	JITP is significantly less importance than the other techniques.
- with respect to quality improvement	TPM is significantly less importance than the other techniques except GT. GT is significantly more important than JITP and UPL

experience in JIT systems (in terms of years of experience) tend to declare that the main purpose of implementing JIT systems is to improve quality and increase productivity of the manufacturing processes,and on the other hand, consider the objective of inventory reduction to be the least important. These lend to support Edward Hay's opinion [22]. Increasing the number of the distinct products in the plant leads to the more concentration on increasing productivity objective.

Table 9. Spearman rank correlations, corrected for ties

	No. of years of personal experience with JIT systems	No. of distinct of product	Local quality weight	Local inventory weight	Local production weight
No. of years of personal experience with JIT systems	1.0000				
No. of distinct of product	0.4247	1.0000			
Local quality weight	0.4783	-0.0387	1.0000		
Local inventory weight	-0.4709	-0.2837	-0.1316	1.0000	
Local production weight	0.3902	0.4327	-0.0247	-0.3664	1.0000
STR	-0.0720	0.1284	-0.0403	-0.3237	0.1543
TPM	-0.1486	0.0390	0.0572	-0.0047	0.0145
PS	-0.1357	-0.0255	-0.0396	0.0765	-0.1631
GT	0.3705	-0.0531	0.1604	-0.2619	0.0271
UPL	-0.1097	-0.0328	-0.1383	0.2432	0.1418
JITP	-0.0631	0.0112	0.2697	0.4012	-0.4180

Maximum difference allowed between ties .00001

CHAPTER V. SUMMARY AND CONCLUSIONS

Based on the survey responses, among the six JIT techniques, total preventive maintenance is viewed as the most important technique to meet the goal of increasing manufacturing efficiency and effectiveness. This program is established to minimize the equipment breakdowns, which reduce equipment down time. The study points out that not only is total preventive maintenance an important concern in JIT systems, but group technology, setup time reduction, pull systems, uniform plant load are at the same level of importance needed to apply to the manufacturing processes also. The practitioner of JIT systems may start at the total preventive maintenance program, which ensure the high process capability. By this program, the line stoppage because of the equipment breakdown will be decreased. At the same way, one may look at set up time reduction program to reduce the lot size or in turn lowering the level of work-in-process. Reducing lot size will cut the inventory and reveal the quality problems in the manufacturing processes. Once these problems have been solved, the number of units to be reworked or scraped will be reduced. This yields the tighter control of inventory and enhance quality which lead to higher productivity.

The other principle of JIT philosophy is to balance and synchronize the production flow. A concept of balance work center is involved. The principle of this program is that the production rate must be equal to the demand rate, no more and no less. According to this, pull systems are used as an information system to signal at each operation which will produce a unit only in response to a requirement from the next operation. As a result, WIP and final product inventory levels are minimized and throughput time will be improved.

Within JIT systems, the work center in the manufacturing process should be laid out by product rather than by department specialty as in the traditional manufacturing type. This principle of cellular manufacturing not only gives more flexibility in responding to market demand, but also reduces space requirements, WIP, material handling, inventory storage, and throughput times.

From the results of this study, it appears that manufacturers emphasize more in applying JIT philosophy to their shop floor first, and place less emphasis on the purchasing area. But this does not imply that JIT purchasing concepts should be disregarded. If there is no buyer and vendor linking, the pull systems concept cannot be applied to the full length of the manufacturing process. These are the cause-effect chain of system that are hidden in traditional manufacturing systems.

Recommendation

Based on this study, out of six JIT implementation techniques, total preventive maintenance is perceived to be the most important technique. One may begin to implement JIT systems by implementing total preventive maintenance program first. Then continue with group technology, setup time reduction, pull systems, or uniform plant load before starting JIT purchasing program.

Suggestions for Further Research

The validity of the current research is based on the methodology used in constructing the problem and is justified by the comprehensive input obtained. The JIT techniques chosen for constructing the hierarchy in this research is limited to only 6 factors, one who wants to further this research may consider other factors as well, which may give a broader view of JIT implementation strategies. This research concentrated on four types of industries which were automotive industry, computer industry, electronic industry, and machinery industry. Similar studies can be made based on other industries. Follow up surveys are recommended, in order to attain more response.

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APPENDIX A: THE QUESTIONNAIRE

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Department of Accounting
College of Business Administration
300 Carver Hall
Ames, Iowa 50011-2065
Telephone 515-294-8106
Fax 515-294-6060

January 16, 1991

To Whom It May Concern,

We are conducting a study of the importance of JIT implementation techniques using a method which requires pairwise comparisons. The purpose of this survey is to obtain information from manufacturing managers concerning these techniques.

Because the study is based primarily on the results of this survey, your response is extremely critical to its success. The questionnaire should take no more than 10-15 minutes. All information will be kept strictly confidential. There will be no analysis of data based on identification of a specific firm.

We would appreciate your assistance in directing the questionnaire to the person in your manufacturing area who is most familiar with JIT concepts and techniques. The completed materials should be returned to us before **Febuary 15,1991** to expedite the completion of this project. If you have any questions about the research study, please feel free to contact Dr. Daniel Norris at (515) 294-5024 or Dr. Victor Tamashunas at (515) 294-7733.

Thank you very much.

Sincerely,

Daniel M. Norris
Associate Professor

Sutthira Thanyavanich
Graduate Student in
Industrial Engineering

SURVEY OF JIT IMPLEMENTATION TECHNIQUES

The purpose of this survey is to evaluate the relative importance of certain JIT techniques in improving manufacturing efficiency and effectiveness. This study uses a method which requires pairwise comparisons of the relative factors.

Background Information

1. What is your job title?________________________________
2. Are there any JIT systems operating in your plant? No__ Yes__ (If yes, go to question 3)

   If there **are not** any, please briefly explain why your company has not implemented a JIT system.

   Stop here and return the questionnaire by folding in half, taping shut, and mailing.

   ____

   ____

3. How many years of experience do you personally have with JIT systems? ____________________
4. How many years have JIT systems been used in your plant?______________
5. How many distinct products are made under JIT systems in your plant?____________
6. What type of products are made under JIT systems in your plant?

   __ Automotive __ Electronic equipment __ Machinery __ Others (Please indicate) ______________

7. What type of manufacturing system is used with your JIT systems? Check all that apply.

   __ Job-shop __ Repetitive __ Others (Please indicate) ______________________________

8. How many manufacturing employees are there at your plant?_____________________________

Pairwise Comparisons

For each pairwise comparison, if the left side item is more important, circle "**>**", but if the right item is more important, circle "**<**". Also, indicate the degree of relative importance by using the following measurement scale:

0	**Equally** important
4	**Moderately more** important
8	**Absolutely more** important
1,2,3,5,6,7	**Intermediate** values

The following are examples:

item A (>) < 0 1 2 3 4 5 (6) 7 8 item B
(item A is *considerably more* important than item B)

item B > (<) 0 1 (2) 3 4 5 6 7 8 item C
(item C is *somewhat more* important than item B)

item C > < (0) 1 2 3 4 5 6 7 8 item D
(item C is *equally* as important as item D)

0	**Equally** important
4	**Moderately more** important
8	**Absolutely more** important
1,2,3,5,6,7	**Intermediate** values

See the Appendix on the last page for the definitions of the terms used.

1. JIT can be implemented for many reasons. Please evaluate the relative importance of the following with regard to the overall objective of ***Increasing manufacturing efficiency & effectiveness***.

Inventory reduction	>	<	0	1	2	3	4	5	6	7	8	Quality improvement
Quality improvement	>	<	0	1	2	3	4	5	6	7	8	Productivity increase
Productivity increase	>	<	0	1	2	3	4	5	6	7	8	Inventory reduction

2. Please evaluate the relative importance of the following JIT implementation techniques with regard to the objective of ***reducing inventory***.

Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	Group technology
Total preventive maintenance	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
Pull systems	>	<	0	1	2	3	4	5	6	7	8	Setup time reduction
Group technology	>	<	0	1	2	3	4	5	6	7	8	Uniform plant load
Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Setup time reduction
Group technology	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance
Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Pull systems
Group technology	>	<	0	1	2	3	4	5	6	7	8	Pull systems
Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance
Total preventive maintenance	>	<	0	1	2	3	4	5	6	7	8	Group technology
Pull systems	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
JIT Purchasing	>	<	0	1	2	3	4	5	6	7	8	Uniform plant load
Pull systems	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance
Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing

3. Please evaluate the relative mportance of the following JIT implementation techniques with regard to the objective of ***Improving quality***.

Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	Group technology
Total preventive maintenance	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
Pull systems	>	<	0	1	2	3	4	5	6	7	8	Setup time reduction
Group technology	>	<	0	1	2	3	4	5	6	7	8	Uniform plant load
Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Setup time reduction
Group technology	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance

0	**Equally** important
4	**Moderately more** important
8	**Absolutely more** important
1,2,3,5,6,7	**Intermediate** values

Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Pull systems
Group technology	>	<	0	1	2	3	4	5	6	7	8	Pull systems
Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance
Total preventive maintenance	>	<	0	1	2	3	4	5	6	7	8	Group technology
Pull systems	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
JIT Purchasing	>	<	0	1	2	3	4	5	6	7	8	Uniform plant load
Pull systems	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance
Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing

4. Please evaluate the relative importance of the following JIT implementation techniques with regard to the objective of ***increasing productivity***.

Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	Group technology
Total preventive maintenance	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
Pull systems	>	<	0	1	2	3	4	5	6	7	8	Setup time reduction
Group technology	>	<	0	1	2	3	4	5	6	7	8	Uniform plant load
Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Setup time reduction
Group technology	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance
Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Pull systems
Group technology	>	<	0	1	2	3	4	5	6	7	8	Pull systems
Uniform plant load	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance
Total preventive maintenance	>	<	0	1	2	3	4	5	6	7	8	Group technology
Pull systems	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing
JIT Purchasing	>	<	0	1	2	3	4	5	6	7	8	Uniform plant load
Pull systems	>	<	0	1	2	3	4	5	6	7	8	Total preventive maintenance
Setup time reduction	>	<	0	1	2	3	4	5	6	7	8	JIT Purchasing

Thank you for completing this survey. We greatly appreciate your cooperation and assistance. Please fold the questionnaire in half, tape it shut (do not staple), and mail it. The postage has been prepaid.

Appendix

<u>*Definition of JIT techniques*</u>

Setup time reduction : is a program to reduce the time taken to setup a machine so that it is economical to produce a small lot size.

Group technology : is a program that arranges the machines or equipment so that material flow is simplified and material handling is minimized. An example of this technique is the U-shape layout.

Uniform plant load : is a program that balances and synchronizes the production flow. In other words, the production of all piece parts of a finished product is synchronized with the final demand rate (market demand rate).

Pull systems : is a program whereby a unit is produced only in response to requirements from the next operation. The completed parts remain at the point of manufacture until withdrawn by the subsequent operation. This provides a visual signal to halt production when parts are not needed.

Total preventive maintenance : is a program of systematic inspection, detection, and prevention of failure in production and support equipment.

JIT purchasing : is an approach where material is purchased when needed, in small, high-quality quantities, and in the specific period required. The relationship between suppliers and the buyer is long-term and mutually beneficial.

Fold here

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APPENDIX B: SOFTWARE PROGRAMS

Expert Choice

Expert Choice is a software package that automates Saaty's AHP model. It is a decision support system which helps decision makers in making complex and unstructured decisions. The pairwise comparisons feature is used to express the relative importance of one variable over another. The program user only evaluate elements by answering questions in any of three ways, in terms of importance, preference or likehood. This allows for a measurement in terms of a ratio.

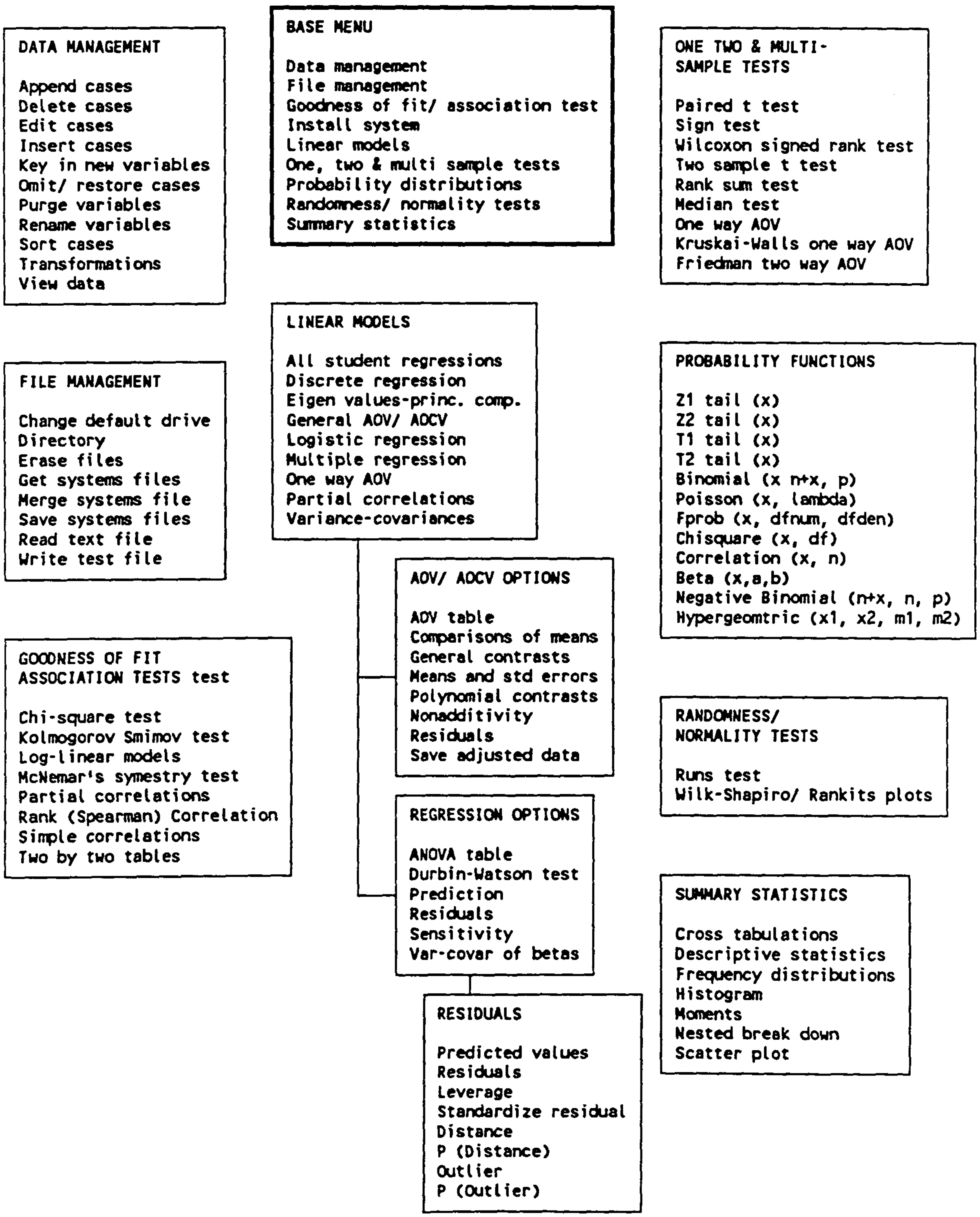
The ratio for all comparisons at each level are combined to give a local priority. The program uses the local priorities to establish a global priority for each alternative by multiplying the local priority of each element by its parent node's global priority. By this method, quantification of the decision elements is cultivated indirectly.

Another mathematical calculation obtained from the expert choice is the determination of a consistency ratio. It refers to the internal consistency of decision maker's judgment. For example, if element A is indicated to be more important than element B, and element B more important than element C, then, logically element A should be indicated to be more important than element C. Expert choice has a proficiency to show where the most inconsistent judgments took place. This feature allows the user to reconsider and make an appropriate change [11].

Statistix

Statistix is a statistic software package used to run data analysis for this research on an IBM compatible personal computer. The good aspect of this software is that it has an interactive environment for manipulating and analyzing data. It is easy to access by the user who has not much analytical experience. It is capable to excel in the analysis of data sets of moderate size. The facility of this software is illustrated in Figure 5.

Figure 8. Statistix Command Tree



APPENDIX C: FREQUENCY DISTRIBUTION & CROSS TABULATION TABLES

FREQUENCY DISTRIBUTION OF TITLE OF RESPONDENT

VALUE	N	
1	3	***
2	1	*
3	1	*
4	7	*******
5	7	*******
6	4	****
7	3	***
8	1	*
9	1	*

NON-MISSING	28
MISSING	0
TOTAL	28

FREQUENCY DISTRIBUTION OF NO. OF YEARS OF PERSONAL EXPERIENCE WITH JIT SYSTEMS.

YEARS	N	
1	1	*
2	2	**
3	5	*****
4	2	**
5	5	*****
6	4	****
7	5	*****
9	1	*
10	3	***

NON-MISSING	28
MISSING	0
TOTAL	28

FREQUENCY DISTRIBUTION OF YEARS OF JIT SYSTEMS IMPLEMENTED IN THE PLANT

YEARS	N	
1	4	****
2	5	*****
3	5	*****
4	5	*****
5	3	***
6	3	***
7	2	**
10	1	*

NON-MISSING 28
MISSING 0
TOTAL 28

FREQUENCY DISTRIBUTION OF DISTINCT PRODUCT

VALUE	N	
1	2	**
2	5	*****
3	3	***
4	3	***
5	2	**
6	5	*****
7	2	**
10	2	**
15	1	*
21	1	*
200	1	*
210	1	*

NON-MISSING 28
MISSING 0
TOTAL 28

FREQUENCY DISTRIBUTION OF NUMBER OF EMPLOYEES

VALUE	N	
60	1	*
65	1	*
69	1	*
70	1	*
80	1	*
100	2	**
130	1	*
150	1	*
200	1	*
250	2	**
300	3	***
350	2	**
360	1	*
400	1	*
450	1	*
500	2	**
650	1	*
700	1	*
750	1	*
1200	1	*
2200	2	**

NON-MISSING	28
MISSING	0
TOTAL	28

CROSS TABULATION OF YEARS OF PERSONAL EXPERIENCE WITH JIT SYSTEMS BY NO. OF YEARS OF JIT SYSTEMS IMPLEMENTED IN PLANT

PERSONAL (YRS)	PLANT (YRS) 1	2	3	4	5	6	7	10	ROW TOTAL
1	1	0	0	0	0	0	0	0	1
2	0	1	0	1	0	0	0	0	2
3	1	2	1	1	0	0	0	0	5
4	0	0	1	0	0	1	0	0	2
5	1	0	2	1	1	0	0	0	5
6	0	0	0	1	2	1	0	0	4
7	1	1	0	1	0	1	1	0	5
9	0	0	1	0	0	0	0	0	1
10	0	1	0	0	0	0	1	1	3
COL TOTAL	4	5	5	5	3	3	2	1	28

CASES INCLUDED 28 MISSING CASES 0

CROSS TABULATION OF NO. OF DISTINCT PRODUCTS BY TYPE OF PRODUCTS

NO. OF DISTINCT PRODUCTS	TYPE OF PRODUCTS 1	2	3	4	ROW TOTAL
1	0	1	1	0	2
2	3	0	2	0	5
3	1	0	1	1	3
4	1	1	1	0	3
5	0	0	2	0	2
6	0	2	2	1	5
7	1	0	1	0	2
10	0	0	1	1	2
15	0	0	0	1	1
21	0	0	1	0	1
200	0	0	1	0	1
210	1	0	0	0	1
COL TOTAL	7	4	13	4	28

CASES INCLUDED 28 MISSING CASES 0

CROSS TABULATION OF TYPE OF PRODUCTS BY TYPE OF MANUFACTURING SYSTEMS

TYPE OF PRODUCTS	TYPE OF MANUFACTURING SYSTEMS 1	2	3	ROW TOTAL
1	1	4	2	7
2	0	4	0	4
3	3	7	3	13
4	3	0	1	4
COL TOTAL	7	15	6	28

CASES INCLUDED 28 MISSING CASES 0

CROSS TABULATION OF TYPE OF PRODUCTS BY TYPE OF MANUFACTURING SYSTEMS

TYPE OF PRODUCTS	TYPE OF MANUFACTURING SYSTEMS 1	2	3	ROW TOTAL
1	0	2	0	2
2	0	4	1	5
3	2	1	0	3
4	0	2	1	3
5	1	0	1	2
6	1	2	2	5
7	0	1	1	2
10	1	1	0	2
15	1	0	0	1
21	0	1	0	1
200	1	0	0	1
210	0	1	0	1
COL TOTAL	7	15	6	28

CASES INCLUDED 28 MISSING CASES 0