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Strategies for implementing the Just In Time manufacturing concepts

Sarah Frances Davies
Iowa State University

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Sarah Frances Davies

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1. INTRODUCTION

What is the goal of a manufacturing company? The question is deceptively simple to answer. To produce a quality product as efficiently as possible? To gain market share and power? The ultimate goal of any company is to make a profit! Any action that brings you closer to attaining that goal is productive, any that doesn't is unproductive. Actions such as stockpiling inventory, running large batch jobs through the job with long lead times, having long set up times are unproductive and do not make money for the company [9].

While the previous statements seem obvious, it is surprising to find that these unproductive actions are common to many manufacturing companies in the United States and indeed much of the Western world's manufacturing organisations. However as competition through manufacturing becomes more and more prevalent, it is increasingly important that only productive actions are used.

Just-In-Time (JIT), Zero Inventory (ZI), Total Quality Control (TQC) and Stockless Production are just a few of the names that have been given to the philosophy of manufacturing developed and implemented by the Japanese automobile manufacturer - Toyota [21, 29].

Each of these names were given to the philosophy by different authors upon their interpretation of the most important concept of the methodology. It is obvious from their interpretations that they view inventory reduction as the main objective of the philosophy. In fact Just-In-Time manufacturing is much more than that. Quite simply Just-In-Time manufacturing entails the elimination of waste in every aspect of the manufacturing plant - from the elimination of unnecessary inventory, defects, unnecessary space on the shop floor, unused material, set-up time and the wasteful use of people [20]. It means re-examining every part of the operation including the attitudes towards people, towards the quality of the product, towards the complexity of the production plan. It entails asking - can this product be improved upon in terms of quality, in terms of the time it took to make it? Can the production process be simplified, can the product design be simplified? Can the attitudes displayed towards the employees or employee relations be improved on?

These questions are not just asked once, but are asked over and over until it becomes impossible to improve the quality and design of the product, impossible to improve the efficiency of the process, and impossible to improve the employee relations. In reality these levels of perfection can never be reached, but it is the philosophy of constant improvement while also emphasizing the simplest, least costly means of improvement that is the basis for JIT manufacturing [22].

The world of manufacturing is becoming more and more competitive with challenges for the top position coming from every part of the globe - the Europeans with their reputation for quality and skilled craftsmen and the developing countries have inexpensive labor and a strong desire to succeed [26]. The Japanese as the innovators of JIT currently hold the top spot with their material control techniques and dedicated work force. Naturally, the Americans are also a very strong force in the race with their sophisticated computer software that controls their production processes.

Much has been written about the success and the failures of organizations that have tried to implement JIT. Certainly the improvements that can be gained by implementing JIT can be considerable. A company that produced automobile exhaust systems, upon initiation of a JIT program, saw a 32 percent reduction in finished goods inventory ($10 million). They removed the need for a 460,000 sq. ft warehouse and allowed the consolidation of two plants. GM cut its annual inventory costs from $8m to $2m and the assembly division increased its inventory turns from 22 in 1982 to 28 in 1984, they have also gained a 60 percent reduction in their obsolescence costs [26]. However for every success story there are several failure stories that depict JIT as being ineffective and nearly impossible to implement [2].

Obviously althougth the concepts of JIT are simple to understand they are not quite as simple to implement. Much of the reason for failure of JIT to be successfully implemented in the U. S. was thought to be the major differences between the American and the Japanese cultures, and the structural and environmental factors. However, as many of the Japanese companies set up plants in the U. S. and used their JIT concepts, it became clear that it was not the culture of the country that determined whether JIT manufacturing would be successful but the culture within the company. JIT is a plan of management action that any manufacturer can implement anywhere in the world. Any worker, when properly managed under this scheme can be as successful and perform as well as the Japanese worker producing products with as high a reputation for quality as the Japanese products.

Although JIT is seen as a recent Japanese innovation, the ideas of JIT were originally stated in Henry Ford's book "My Life And Work" [11]. The lead time, from receipt of iron ore at his River Rogue operation, to casting the engine block, and to shipment of the machine engine block in a final assembled car was just 48 hours! Influenced by Ford's ideas and after instruction in quality control by the Americans' Deming and Juran, Toyota initiated the JIT inventory control method.

Japan has not always been at the forefront of the manufacturing productivity world [25]. For the first half of the century, U. S. productivity reigned supreme thanks mainly to the development of Scientific Management which emphasized factory efficiency and standardization through industrial management. During this period, Japan lagged behind the US and Europe due to their poor resources and their efforts to recover from the war. After their recovery, they concentrated their efforts on JIT and TQC, while in the U. S. the move was being made towards better production and inventory management using sophisticated computer systems such as the Materials Requirement Planning (MRP) system that were aimed at job shop manufacturing with a large diverse ranges of products to produce. The Japanese techniques were being aimed at high volume repetitive manufacturing with goals of high quality and low cost.

These two systems continued to be improved and advanced in their respective countries with little regard for the other system until the oil crisis of 1973. With this crisis the industrial world suddenly had to deal with the elevated costs of basic materials and fuel. Until this point in time there had been little motivation towards the need for resource efficiency. The thought in the Western world had been that the resources would always be readily available and at an acceptable price. Thus the manufacturing systems of the Western world placed very little emphasis upon the need for tight controls over materials.

Manufacturers worldwide, soon realised the need to become more efficent in production. But it was the Japanese that took the need most seriously and implemented tighter material control techniques. This was probably due to the fact that Japan had very few of its own natural resources, thus it was most seriously affected by the crisis.

While Japan totally reevaluated its production system, the west initially tried to find political and economic solutions for avoiding the energy crisis. Once the crisis had become old news, western manufacturers concentrated their efforts on improving the MRP software incorporating complex mathematical algorithms to calculate inventory levels and scheduling plans. The MRP system for planning and control was thought to be one of the best tools for manufacturing management. However, once the effectiveness and simplicity of the Japanese techniques were observed, many questions were asked about the necessity of such complex system as MRP.

Also, the competitive advantage that the Japanese were enjoying in the fields of electrical and automobile items was causing considerable concern, and many U. S. competitors were curious to find the reasons for the Japanese success' in manufacturing [13].

Many companies are in the process of implementing the

JIT techniques - with varying degrees of success! There appears to be an overall plan for implementation that is extremely general. Understand the concept, determine applicability and implement in your own way according to your company's needs. Nobody wants to be too specific and give actual details of exactly which techniques are important and vital to the successful implementation of JIT. It may in fact be the case that there is no blueprint plan for implementing JIT that will guarantee success.

This paper will attempt to evaluate the strategies used by companies in implementing JIT, trying to find a common pattern particularly with respect to the manufacturing techniques used. It will concentrate on the manufacturing aspects of Just In Time implementation, rather than the delivery aspects of the philosophy. If a pattern arises in the strategies then it will propose a possible strategy for implementation. Sources of information for the paper come from published literature in the form of case studies, plant visits to some local manufacturers and from a survey sent to approximately thirty companies that claim to have successfully or are in the process of implementing JIT.

2. LITERATURE REVIEW

The main champion and proponent of Just In Time manufacturing is the American Production and Inventory Control Society (A.P.I.C.S.). In 1983 A.P.I.C.S. established the Zero Inventory Crusade - a committee charged with introducing the concepts of JIT to the manufacturing industry in the United States. A program of Zero Inventory (the synonym adopted by A.P.I.C.S. for Just In Time manufacturing) seminars were scheduled to be held on an annual basis. These were one hour programs informing production and inventory control managers in corporations of Just In Time and its philosophies. They were delivered at Chapter dinner meetings. Consequently, much of the Just In Time literature has been published through A.P.I.C.S., and has thus tended to be of similar thought.

Much of the literature begins by stating the authors opinion of what the philosophy of JIT actually is. Heard states [16] "Strive to find and use the simplest and least costly ways to plan, schedule and control the flow of material throughout the manufacturing process. This is done by following several ideals :

- Produce only the products that the customer wants
- Produce the product only at the rate that the customer wants
- Produce the product with perfect quality
- Produce the product instantly - zero unnecessary lead time
- Produce with no waste of labor, material, energy or equipment, every move with a purpose so that there is no idle inventory.
- Produce by methods which allow for development of people"

Sepehri states [26] "The concept of JIT is to have only the right part in the right place at the right time. Having one

extra part is a waste because it is not needed at that place or at that time."
He also states that "JIT is a quest for manufacturing excellence, to be accomplished through the pursuit of an ideal - that of zero inventory levels."

In trying to attain this ideal, complete elimination of waste is needed - in terms of time, energy, material and errors. Ultimately, the result of this is cost reduction.

Robert Hall [11], who wrote a very comprehensive book "Zero Inventories", further stresses the importance of reducing inventory levels in his analogy of the river flowing over the rocks on the river bed. Here, the water level symbolizes the level of the inventory and the rocks are the problems within the manufacturing process such as long set up and queue time, poor layout and quality and poor tool design. As you force down the water level more and more of the rocks appear. As the inventory level is lowered, more and more quality and production problems appear and are consequently solved.

Thus the initial literature appears to suggest that to implement Just In Time, one simply needs to reduce the inventory levels and then solve the production and quality problems as they occur. While the concepts of JIT appear simple, and can be implemented without major expenditure by the company, "the implementation of JIT requires the commitment and leadership of top management and at the same time the understanding and full dedication of every individual involved in the process [26]."

Throughout all the literature, one underlying factor is stressed for the successful implementation of Just In Time. That factor is the commitment of the people involved. Without the support, understanding and conviction of the people involved - from top management to the bottom operators, the system and all efforts to implement Just In Time manufacturing will fail [22].

The Japanese call this aspect of JIT 'Respect for Humanity'. Everybody within the system has to know what the system is supposed to do, how to develop it and how to refine it. In practice, this means that each worker is treated with respect and trust. They are acknowledged as an important and necessary part of the production operation, made to feel part of the team, with their contributions being vital to the product. This desire to impress upon the operators how vital their contribution is, is even shown in the wage system in Japan.

Hayes and Wheelwright [13] state that at the end of the year the bonus is given totally to the operators, as it is they who have actually contributed the most to the successful production of the process. This change in attitude toward an operator refers back to the culture within the company being all important to successful Just In Time implementation

Monden [21] further reinforces this belief in stating that the two most important factors of the Toyota Production System (so-called 'the definitive JIT system') were JIT production and Autonomation.

There now seem to be two critical factors to the implementation of Just In Time - the reduction of inventory levels and the commitment of the people involved.

Just In Time production is, as the name states, the production of pieces only when they are needed, i.e., in the production of a car - the necessary sub assemblies of preceding processes should arrive at the final assembly line at the time needed in the quantities needed. Thus, the operators are called upon and trusted to produce only enough parts at the correct time so as not to hold up production or over produce. In order to operate JIT perfectly - one hundred percent defect free parts must be produced and flow to the subsequent process without any unnecessary delay. This flow must be rhythmic and without interruption - therefore quality control is vital and should run concurrently with Just In Time production [2, 28].

Autonomation is the mechanism which prevents the mass production of defective work. According to Monden, the system allows the worker to halt the production of his machine and also the whole production line when he finds that his machine is producing defective work. An autonomous machine is one which has an automatic stopping device attached to it. Should a defective part be produced the worker is able to stop the machine and hence the whole line. At this point any worker in the area who is available is encouraged to go to the area and contribute whatever they can in the attempt to remove the reason for the defective work. It is clear from this practice why operator trust and respect is so necessary for successful implementation of Just In Time. If the operator felt that his contribution was not vital to the operation, he may have doubts about the necessity of stopping the whole production line when defects occurred. He needs to understand the entire operation, so that he can see how the work that he does on the part fits in with the rest of the process and why it is necessary. It is also important that the worker feels a sense of pride in what he is contributing to the product, and to the product overall. He is as responsible for the quality of the product and consequently the reputation of the product and the company, as is the Chief Executive Officer of the company.

Sepehri [26] continues "after the people, the next most important factor in successful Just In Time implementation is the Environment and then following that the Systems."

Serious changes need to be made within the manufacturing plant - factors previously seen as fundamental constants now need to be realized as possible variables that can be optimized. A prime example of this is the Economic Order

Quantity equation that is used by most Material Requirements Planning systems in U. S. production [17].

$$EOQ = \sqrt{\frac{2.A.S}{I.C}}$$

A = annual usage
S = set up cost
I = inventory carrying cost
C = unit cost
q = quantity ordered

$$T \text{ (total cost)} = \frac{A.S}{q} + \frac{I.C}{2} + A.C$$

Conventional U. S. manufacturing techniques tend to move towards larger lot sizes (EOQ sizes), in order to reduce the effect that the cost of the set up has per piece and thus bring down the unit cost per piece. This philosophy assumes that costs such as set up, inventory carrying and unit cost are all constant and cannot be altered.

Just In Time philosophy refuses to admit that any of these costs or factors are cast in stone. The philosophy assumes that all the factors are variable and thus can be improved upon - hence one of the main manufacturing concepts is to reduce the set up time on a machine for an operation. By examining the EOQ equation, it can be easily shown that if the set up cost is reduced then so can the EOQ! Efforts to reduce the set up time provide not only improvements in lot size but also a reduction in lead time, inventory levels and hence inventory carrying costs.

The attitudes or mind-set of manufacturing personnel also need to be changed. Robert Ames [1] compares the differences in attitudes of the conventional manufacturers and the JIT manufacturers:

"Conventional Attitudes:
- Some defects are acceptable
- Large lots are economical
- Faster production is more efficient
- Inventory provides safety
- Inventory smoothes production

Just In Time Attitudes:
- Zero defects necessary and attainable
- Ideal lot size is one piece
- Balanced production is more efficient
- Safety stock is waste
- Inventory is the root of all evil!!"

Just In Time manufacturing doesn't depend on specific techniques so much as it does on the different mind-set and attitude of all those involved in its implementation. The recognition of the fact that none of the factors previously believed to be constants in manufacturing, should be seen as constants, is crucial to the successful implementation of Just In Time.

Although Just In Time appears to utilize and indicate methods of manufacturing that are completely opposite to conventional techniques, it does advocate some methods that are also familiar to U. S. manufacturers such as Group Technology and the focused factory concept.

Group technology [18, 35] is the consolidation of individual manufactured parts into families of similar parts in the interest of design, planning and manufacturing efficiencies. Grouping components and operations not only simplifies the planning process but also provides possibilities for joint set ups. This grouping of machinery leads to GT cells. GT cells were originally thought to be most useful in the high volume production environment, which is also where Just In Time appears to be most successful. However, the use of GT cells in Job Shop environments enables Just In Time to be successfully implemented in the Job Shops also.

GT cells appeal to Just In Time implementers for a variety of reasons:

Ed Heard states [14] " - design simplification and standardization of the parts. This leads to higher volumes of similar parts which will increase the potential for a focused factory, thus improving delivery, cost and quality.
- fewer process planners and distinctive routings are needed
- higher volumes of similar operation sequences increase the opportunity of dedicating machinery to the same task.
- the use of GT cells also improves the compactness of the layouts. Parts move shorter distances between operations, allowing for lead time reduction (in the form of queue time) and smaller batch sizes. Also, work in process levels and material handling cost should be reduced."

These advantages are common to both philosophies of manufacturing, however Just In Time proponents advocate using GT cells in a way not previously thought of. Instead of running parts requiring the same set up back to back, extraordinary efforts are made to reduce the changeover times. Once this has been accomplished, it becomes feasible to run small batches of different parts back to back - which is necessary for mixed model production, another concept of

Just In Time manufacturing.

Finally, third in importance to the successful implementation of Just In Time, according to Sepehri [26] are the systems. Once the first two criteria of people commitment and environmental change have been satisfied, only then can the various techniques of Kanban, mixed model production, autonomation, etc., can be implemented.

Authors are quick to point out the three main factors of Just In Time as being - People commitment, Quality, and Elimination of waste within the manufacturing process. However there appears to be no clear conviction among them as to which of these factors is of overriding importance. While Sepehri has stated that people commitment is the crucial factor, Robert Ames [2] claims that "Total Quality Control is a necessary foundation for Just In Time". In this article, he states that only 100% quality is acceptable, and necessary for Just In Time manufacturing to succeed.

A more in-depth analysis of the 'Waste Elimination within manufacturing' factor is hard to find in the literature. Many case studies have been written documenting the progress of Just In Time implementation, however very little emphasis has been placed upon which of the manufacturing techniques were crucial.

David Taylor [32], in a paper to the Zero Inventory seminar of 1983, is brave enough to tentatively suggest the following procedure for Just In Time implementation:

"1) Read Literature - educate all the key individuals in the organization. Understand the system - how and why it works, what needs to be done and when.
2) Management support is necessary. Management must be convinced of the need for the system and believe in it and show 100% conviction.
3) Final Assembly, build linearity - build the same quantity for a period of time, use a fixed mixed schedule. Obtain at least 90% linearity in daily production
4) Improve cycle times using Kanban, reduction of inventory, reduction of throughput time and set up time.
5) Reduce inventory levels, work in process levels. Begin Just In Time program with vendors.
6) Simplify the system - review the shop floor control, layout, material recording system, scheduling etc."

Some authors contend that there is no blueprint for successful implementation, and that it depends very much on the people and production process involved.

Certainly from the literature available, there seems to be no clear strategy for implementing Just In Time. There are as many cases documenting the failures of organizations to implement Just In Time as there are success stories. Also, the question needs to be asked of those companies claiming successful implementation of how much of the manufacturing process is running under the Just In Time philosophy? Many organizations have incorporated several GT cells into their regular manufacturing methods and then claim to be running totally under Just In Time successfully.

This paper will attempt to define specific criteria with respect to manufacturing techniques that are necessary for successful Just In Time implementation.

3. THE STATE OF U. S. MANUFACTURING TODAY

3.1 U. S. Manufacturing - History and Reasons for its Present Condition

The seventies and eighties had been predicted to be very promising for the American manufacturing society. However due to a series of unexpected jolts - both internal and external, the state of U. S. manufacturing and its position as the premier manufacturer in the world soon became a fact of the past. In 1971, for the first time in almost a century, imported manufactured goods into the States exceeded the exported manufactured goods. This imbalance continued for ten of the next twelve years. Inflation rose to double figures and the exchange rate between the dollar and other currencies weakened considerably. Suddenly, there were serious foreign competitors who were taking major chunks of the U. S. manufacturers market share.

One measure of the failure of U. S. economy was summarized by the productivity of the private sector. Since the end of World War II productivity had increased by an average of three percent per year up until 1976. Then productivity essentially stopped growing, as a result the unit labor cost increased by more than 25 percent between 1976 and 1981 [13]. This deterioration in productivity in the U. S. was faster than in competing countries and so undermined the U. S. position within the manufacturing market and on the standard of living index. It also undermined its ability to effectively compete with other countries.

At the realization of this situation, the methods that management were using to govern their companies were called into question. Even after 1983, when the economic recovery began, the concern was still there - largely due to the fact that the economic recovery was worldwide, thus all countries were benefitting from the same factors that the U. S. was benefitting from. So, the U. S. was no longer the premier manufacturer for certain products. This was especially true in the high-technology markets such as semiconductors, computers and consumer electronics where there were now serious challenges from the Japanese. By 1983, the Japanese television manufacturers dominated several U. S. market segments providing products that had originated in the United States. Initially, the reason given for this was that the Japanese had lower labor costs, but by this stage many of the large U. S. producers had 'offshored' their production lines and so were also 'enjoying' the same low labor costs. Similarly, the German machine tool and automotive producers bit deeper and deeper into the U. S. domestic market even though their labor rates rose above those of the United States.

Many reason were given for the U. S. inability to be competitive with other producers:

- the growth of the governmental regulations and taxes.
- a deterioration of the work effort which together with the adverse relationship between labor and management had produced a series of crippling strikes.
- interruptions in supply and rapid increases in energy forms since the OPEC event of 1973 [25].
- a large influx of minorities into the workplace market - such as teenagers, women and other minority groups that all needed to be trained and conditioned to work in an industrial environment.
- due to the high inflation rates, there were unusually high capital costs.

These reasons all appeared to be valid until it was realized that the stagnation of American productivity growth had started before any of these reasons had become applicable.

Comparisons were soon made between the ways that the U. S. managed their organizations and the way that the Japanese and Europeans managed their organizations. It became clear that the Japanese and Europeans differed from the U. S. in their goals, assumptions about how the competitors would act, and the techniques that they used to implement their decisions [13]. The U. S. had taken for granted its superiority in technology and management practices for many years, and had never bothered to study how the competition were operating or how fast they were improving.

Many U. S. companies have often treated making manufacturing decisions on an ad hoc basis. As a decision needs to be made, it is made with no regard to the future consequences of it, or the possibility of the linkages between these decisions. This approach has resulted in serviceable and workable operations but has not created a manufacturing organization that can withstand and prevail against competitors whose philosophy is one of competing through manufacturing.

Once this decline in productivity growth was realized, other factors were examined such as investment in new capital and investment in research and development. Both factors appeared to be increasing at a steady rate until adjustments for inflation, for changes in the workforce and for increases in the real gross national product were made. These factors were also found to be effectively decreasing. This trend was now more ominous because of the long term effects of a decrease in capital equipment and research.

Productivity is a useful way of measuring the efficiency with which resources are consumed in producing goods and services. Efficiency is primarily a management responsibility. Thus, management look to increase efficiency.

They can do this through a combination of three approaches:

1 - Short term

Use existing assets more efficiently on existing products

2 - Medium term

Substitute a new set of resources for existing ones - such as equipment for labor. Obviously this requires capital and a willingness to take financial risks.

3 - Long term

Develop a new product and processes at a higher level of productivity.

U. S. manufacturers have excelled in the short term approach but have spent very little time utilizing the second and third approach which has resulted in their present predicament.

U. S. manufacturers have taken on a mind-set of 'no-risk' over the last ten to fifteen years, an attitude of 'if it works, then don't try to change it'. This attitude is also emanating through many of the modern management manufacturing textbooks in the U. S. Thus, many managers have followed this approach, which has led U. S. manufacturing companies to:

1 - Emphasize analytical detachment and strategic elegance over hands-on experience and well managed line operations.

2 - Focus on short term results rather than longer term goals and capabilities

3 - Emphasize the management of marketing and financial resources at the expense of manufacturing and technological resources.

Thus, as time progressed and these changes took effect, the U. S. manufacturing companies lost their ability to compete on the basis of technological superiority. While these approaches are not obviously detrimental to the philosophy upon which a company operates, they do subtly shift the emphasis of the company in the following ways:

There is a move to alter the organization of the company into profit centers. The advantage of these centers is that they are highly flexible - capable of responding quickly to growing markets, consumer needs and competitors actions. They tend to develop broad product lines with a host of incremental product improvements to meet the specialized needs of a number of small market segments. These centers tend to be less effective when they need to make major product or process changes that render existing products or equipment obsolete.

Also, senior management tend to judge the success of a profit center on only one criteria. The bottom line! With these centers covering different areas of geographic and economic nature, it would be hard to find many comparable criteria that would have the same weighting at all centers. So, senior management who have little firsthand knowledge of these centers focus their attention almost exclusively on the net profit for the period and the rate of return on the capital invested in that center. Thus, profit center managers, aware of their superiors concern for profit, concentrate on obtaining short term financial results. In order to improve the return on investment, profit center managers can either increase the profits which is difficult and would take a long time, or the manager can decrease the investment which is often easier and takes less time.

The most obvious way of reducing investment is to delay replacing old equipment, of low book value, with new equipment. Other ways are to allow the performance of equipment to deteriorate by reducing maintenance or by replacing machinery, as it wears out, or to replace it with less productive equipment. A whole manufacturing process can be obsoleted by continually replacing it with worn out equipment or equipment that is based on the same technology, rather than with equipment that utilizes newer technology.

Another result of these approaches, has been that many of the top positions in companies are now held by executives with financial, accounting, and legal backgrounds. As a result, fewer of the top executives have had experience in the more competitive functions of the company such as production, engineering and marketing. Thus young managers who are looking for the path to the top see that there is no need to get any hands on experience in production or design, etc. Thus many of the senior executives of many corporations have little or no idea of the factors needed to produce, design or sell the product.

This lack of detailed familiarity for the manufacturing needs of the product has led to a poor appreciation by management of manufacturing technology. Management has failed to realize the need to keep abreast of the new technology with respect to the product and the equipment needed to produce it. A failure to use state of the art equipment and processes to produce a product will often result in the inability of the company to produce innovative new products.

It has become clear that U. S. manufacturers over the past 15 to 20 years, have decided to compete primarily on factors other than their manufacturing ability. While in the short run this had a positive effect on profits, in the long run it has created the situation that the U. S. is currently in!

3.2 The Importance of Using Manufacturing as a Competitive Edge

If the manufacturing role within a company is properly managed and organized then it can play a major role in helping a company attain a desired competitive advantage.

Within most organizations, manufacturing is seen as having a negative impact. Thus, organizations seek to minimize its impact. Even in many of the well-run firms manufacturing plays only a neutral with management believing that marketing, sales and research and development provide better bases for achieving a competitive advantage.

The main competitive criteria that a company chooses to operate by will also dictate the style of manufacturing that they use. A company's competitive criteria may seek high profit margins and thus produce in low volumes, alternatively they may desire to produce high volume products receiving low profit margins on each unit.

Price is perhaps the most typical competitive criteria that many companies use, other criteria could be quality, flexibility and perhaps dependability. Competing in terms of quality assumes that the market is willing to pay for it. Dependability is not necessarily the same as quality, the product may be priced higher than others even though it is not necessarily superior in terms of technology or performance. It would however work as specified, be delivered on time and has an excellent maintenance program. The flexibility criteria reflects both product flexibility and volume flexibility. A business may be able to produce extremely customized items or produce to a volume that is not of regular size. Usually smaller companies operate on this criteria.

Within a given industry, different companies will place different emphases on these criterium. It is essential that they do not give equal priority to each of these criteria and pick one as being the main criteria on which to establish a competitive advantage.

Once the criteria have been chosen, the manufacturing process should be established so as to promote this advantage as much as possible. Manufacturing needs to communicate with senior management on the constraints that it operates under, the capabilities that it can exploit and the options that are available to it. Equally as important, it must establish functional relationships with other departments of the organization.

The companys' philosophy and competitive criteria specifies the type of organization that it wishes to be, and how it is seen by other companies, the public and the stockholders. It is important, therefore, that as many of the employees of the company believe in this philosophy as possible for the company to be a success. As most of the employees will be operating within the manufacturing division, it is obvious that manufacturing plays an important role in keeping this philosophy intact.

4. ORTHODOX U. S. MANUFACTURING TECHNIQUES

There are three main blocks that make up the production system:

1 - the technology of the capital equipment used in production.

2 - the organization of the production system [34].

3 - the techniques of production management that are applied to control the operation of the system [7].

It is this third factor that this chapter will describe. It will detail the methods used to forecast the demand for a product, calculate the monthly demand, then produce the demand for all the sub components that are used in forming the product. Having ascertained the demands for all items, the next stage is to calculate the manpower and machine capacities needed to produce the required parts. At this stage, a list will have been produced of all the parts needed, the machines that the parts have to run on, the time that it will take to produce the order on the machine and the number of men that are needed to run the machines. The last task in the production control system is the most complex - scheduling. The orders must be scheduled so that each operation is finished at the correct time in order for the next operation to commence as soon as that machine allows.

In order to calculate these values, a large amount of information is required. Most conventional production control systems are centred around a complex database system.

The information for these values is obtained from three sources:

- The bill of materials

This is a master list of all the component parts, sub assemblies and purchased part that are needed to produce the finished item. It details the items, the quantities needed for each finished product and the lead time for each part to be available for use in the production process.

- The production routing sheet

This describes the sequence of work centers through which a part will travel. It also provides information on the operations that will be performed at each work center - such as a description of the operation and the time standards for the operation.

- The operations process chart

This chart ties together the production routing sheet and the bill of materials by describing the flow of the components, purchased parts and sub-assemblies through to their final assembly into the finished product.

Throughout all of these charts and sheets, adequate cost and time standards are needed to provide estimated standard costs for the final product.

The production planning process is a chain of events, which are linked together in a specific order. If the chain is broken in anyway, then inefficiencies will result - in the form of higher inventories, longer lead times, higher product standard cost, over utilization of equipment, poorer quality, etc.

The production planning process can be displayed most clearly by a flowchart, as shown in Figure 4.1.

For successful production control, each of these elements needs to be carried out in the specific order stated. This is due to the fact that the information for one step is mainly derived from the previous step. Thus, the accuracy and consistency of the system depends upon each step being carried out to its full extent, so that the information can be used in the next phase.

4.1 Aggregate Forecast

The purpose of this step is simply to derive an estimate of future demand for the product using past data as the main indicator. In most cases, the value forecasted is expected sales for all products. Forecasts tend to be considerably more accurate when they are calculated for a family of products rather than for a specific item. There are several

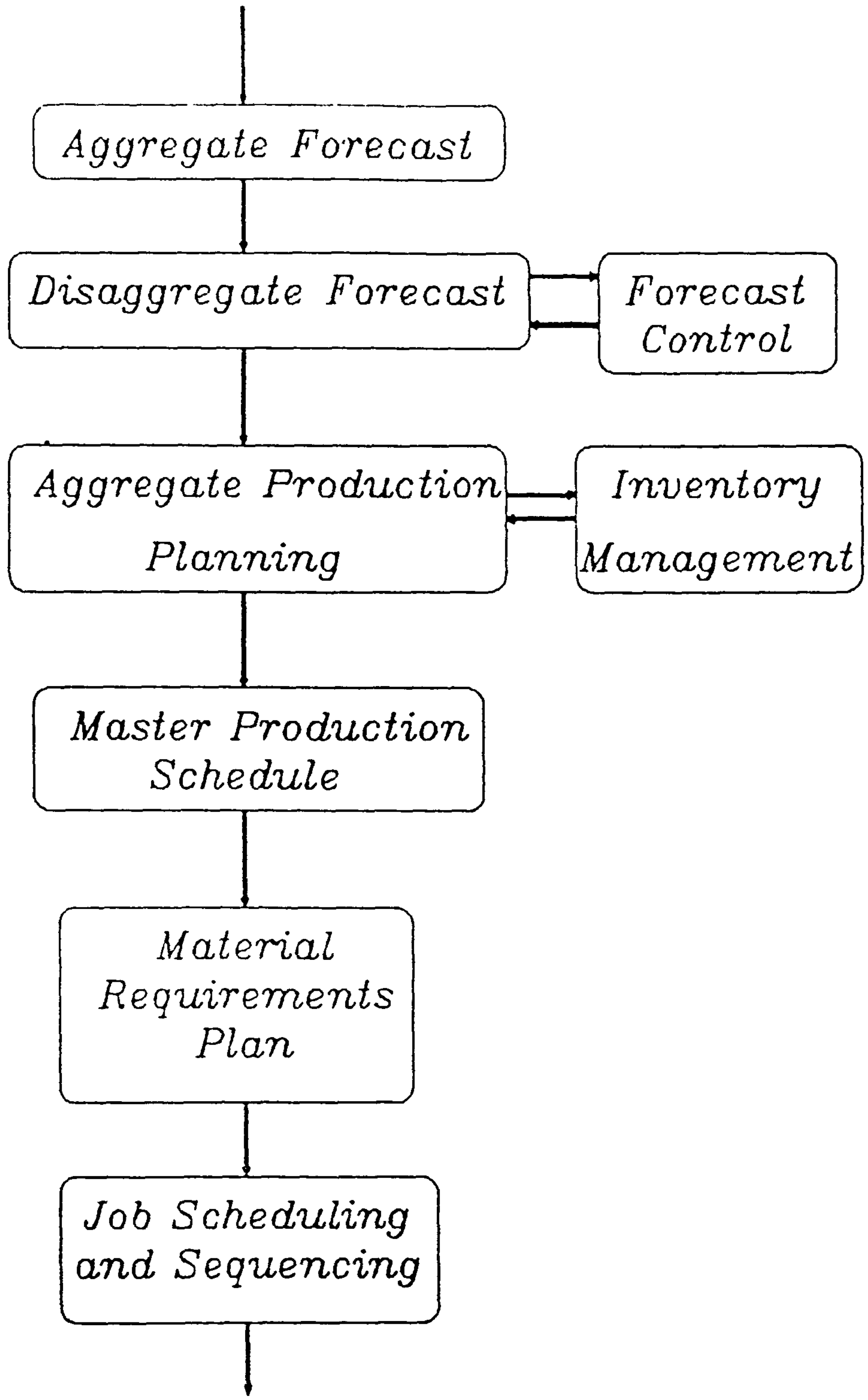

Figure 4.1 Flowchart of the Production Planning Process

possible ways of forecasting the expected sales:

Qualitative models:

Use historical analogy - compare the future period with a similar period for some previous time

Delphi method - send out questionnaires etc., asking for expected sales estimates. Average out the results.

Executive opinion - very often the senior management within in the company will have enough experience to make fairly accurate predictions of expected sales

Quantitative models:

Time series analysis	-	moving average techniques
		exponential smoothing
		time trending
		ratio - to - trends
		Fourier analysis
		Box Jenkins analysis
		CENSUS II, X-11
		FOCUS forecasting
Causal models	-	correlation analysis
		simple regression
		multiple regression
		econometric models

Box Jenkins econometric interface

Time series analyses treat a sequence of observations as a function of past history. Causal models are more often used to predict economic behavior.

Forecasts are also qualified according to the time period that they are calculated over [13].

Immediate forecasts:

These forecasts are used for material adjustments in inventory and raw material requirements. Typically, the forecast runs for one hour, one day or one week. It is highly dependent on the type of product being produced. Of all the forecasts the immediate forecast is the most accurate.

Short term forecasts:

Used to determine labor levels within the manufacturing environment. They run from one week to one month usually.

Medium term forecasts:

The time period for these forecast runs from one year to five years usually - again as with all forecasts, the period that they apply over is dependent on the nature of the product. This forecast usually determines the capital equipment needs over the time period.

Long term forecasts:

Predicts for five years or more. Mainly plant location decisions.

Very Long term forecasts:

This forecast is extremely general, the least accurate of all of the forecasts. It is used to try to predict future technology changes.

4.2 Disaggregate Forecast and Forecast Control

As was stated, the forecast is usually determined for a family of products. The next stage is to break down the forecast for the family of products into an individual estimation of the expected sales for each item.

The first stage in this is to obtain the sales for the previous year of each item. An ABC analysis is then used to rank the items according to the amount of sales that they generated last year. The top 20% of items with the greatest sales being classified as 'A' items, the next 30% being 'B' items and the final 50% - 'C' items [7]. The fraction of sales that each item was responsible for last year is now used to find the proportion of expected sales that the item is predicted to sell over the next time period. The proportion of sales together with the price of the item is used to calculate the number of units that need to be produced.

Forecasts are obtained for each item, usually on a per month basis. As each month of production passes, the actual demand and forecasted sales are compared to evaluate the accuracy of the forecast. Forecast control techniques are used which track the error between the forecast and the actual sales and use this value to predict whether the forecast needs to be readjusted or the resources for the month in question need to be altered.

4.3 Aggregate Production Planning

It is at this stage that the immediate and short term forecasts become vital. Production needs to be planned in the form of hours on the machines and in the manpower needed to produce enough of the product to satisfy the demand. To determine the load on the machines and on manpower, there are many strategies for calculating these requirements. There are however, four so-called pure strategies for planning production. The primary output of the aggregate production plan is a Master Production Schedule (M.P.S.). The MPS will describe the number of units to be produced during each time period and also the work-force levels required per period. The four pure strategies are:

- Inventory levelling

A master production schedule is determined such that the same amount is produced every week throughout the whole year. In this way, there will be times when there will be an excess of inventory which will be placed in storage. There will also be instances where production will be less than the demand, in these cases the demand will be satisfied from inventory stores. The major cost incurred with this strategy is the inventory storage cost.

- Hire and Fire

This master production schedule follows the demand exactly - producing exactly what is required at the time required. The situation arises that at certain times there will be excess capacity, while at other times capacity will be operating at its limits. This strategy involves hiring and firing employees to alter the production level as the demand occurs. Thus, for months where there is a high demand, more employees will be hired, for months with low demand employees will be fired. Here, the major costs are the costs incurred in hiring and firing the employees.

- Overtime

This strategy involves hiring employees to the lowest level of demand, and then having the employees work overtime to produce the extra demand. The cost of the overtime needs to be taken into account when calculating the cost of this strategy.

- Subcontracting

Again, employees are hired to the lowest level of demand for the year. In this case all excess demand is sub-contracted out to smaller manufacturers.

It is also equally likely that, the strategies may be combined in some way, for example, a combination of the sub-contracting and overtime strategies could be used.

It should be noted that there are many other models that can be used to develop the M.P.S., these models are often more complex and will contain many factors. Such techniques used to develop the M.P.S. include dynamic programming and networking theory. A cost function is obtained for each of these strategies, the aim is naturally to minimize the function. However, the manager of the manufacturing department may not necessarily choose the minimum cost solution. There are many other factors that are not included in these analyses that need to be taken into account such as employee morale, the relationship with the union, the condition of the equipment, the location of the plant, the availability of skilled labor, the timing of when the product is to sold. These are factors that are hard to put a numerical value on and so must be evaluated separately.

Along with the development of the Aggregate Production Plan, inventory management strategy is also developed at this time.

Inventory is the raw material, semi-finished parts and assemblies, and finished goods that are in the production system at any point in time. In conventional manufacturing, inventory serves as a buffer between stages of the process to allow for any defects in product, breakdowns of the machinery or any other unplanned delays. The main aim is to ensure that the product can still be delivered to the customer on time.

In developing the M.P.S., further analysis needs to be carried out to determine how much of the product should be made in one order - i.e., what is the lot size? Also, when should the orders be placed so as to minimize the inventory costs?

Inventory costs can be classified into three separate costs:

- the cost of carrying inventory

This cost involves the opportunity cost of money being tied up in inventory, the storage and space charges for providing storage space, taxes and insurance, and the cost of deterioration and its prevention, the cost of ordering and receiving the inventory and finally the cost of obsolescence.

- the cost of incurring shortages

This cost is incurred if inventory is not available when it is needed. It is the cost of lost sales, loss of goodwill, customer dissatisfaction, and extra administration work resulting from the inability to meet the required demand. It is the most difficult of all of the inventory costs to estimate. Shortage costs can be separated into two types - the cost of a shortage irrespective of the amount of stockout and secondly the cost of the shortage per unit of stockout per unit of time.

- costs associated with manufacturing

These costs are incurred where stock is produced in production runs or batches within a plant rather than ordered from outside. Here, the cost will be associated with the time lost in changing over from one product to another. To reduce this cost, production runs are made longer - which corresponds with higher order quantities.

There are two main disciplines in determining the lot size:

- Periodic review:

Under this policy, the inventory levels are reviewed at equal time periods. If at the end of the period, the inventory level is higher than a predetermined reorder level, then no order is placed for more of the product. However, if the level is less than the reorder level an order is placed to bring the inventory level up to the maximum inventory level. The advantage of this system is that it allows the simultaneous ordering of many items giving bulk delivery and quantity discounts. It also requires much less stock monitoring [7].

- Fixed order quantity:

Under this system, orders of a fixed size are placed when the stock level falls to a certain level - the reorder level. If demand is high, orders are placed more frequently than if demand were low. The advantage of this system is that theoretically there will be a lower average level of stock for a given amount of protection against a stock out.

Under these policies, there are a multitude of variations that include the ability to take into account:

- the effect of quantity discounts,
- back ordering,
- multi product ordering,
- restrictions on the number of orders that can be placed in a time period,
- situations when the demand is a function of selling price,
- manufacturing models that include set up costs and production rates,
- probability of uncertainty in sales,
- also cases where the demand and lead time have statistical probability distributions [17].

Using the aggregate production plan together with the inventory lot size problem, the master production schedule is produced. At this point the schedule shows the quantities of final product needed and their due dates. This schedule is then broken down into demand for each component part and the date that that part is needed by for production of the final product. This new schedule is known as the Material Requirements Plan.

4.4 Material Requirements Planning

From the master production schedule, the demand for the final end item is known and also the time when it is needed. However, the M.P.S. does not give any detailed information such as the flow of the component parts and sub-assemblies through the shop floor. In a product layout or flow shop, the disaggregate plan is usually good enough to produce workable production plans. In the job shop, this is not the case. The flow of the product is considerably more complex. Components move independently throughout the shop sharing common resources. As a result, it is vital that the components are scheduled to be produced at the right time in the right quantities. Most organizations build high buffer stocks of work in process inventory between departments and operations to ensure that the capacity is utilized to its full extent. To deal with the complexity of these timings and inventory relationships, Material Requirements Planning was developed.

At this stage it is important to realize the difference between dependent and independent demand. Independent demand is the demand for a final product, it can only be arrived at through forecasting methods. Dependent demand is the demand for all the components and sub-assemblies of the product.

This demand is dependent because it is determined by the demand for the final product. The only cases where demand for components and sub-assemblies is independent is as spare parts for servicing and maintenance.

Using the Bill of Materials, routing sheets and production times for each component part together with the M.P.S. of the final product, the production times and quantities of each of the components can be calculated. The M.R.P. will also provide information for purchased part requirements and times to order. The system also needs comprehensive information on the current inventory levels within the system

The majority of M.R.P. systems are computer based. Typically, the M.R.P. software packages will provide the following reports - gross and net product requirements, a capacity versus load on the machines report, a shop floor planning report, and a production order, status and exceptions report.

The M.R.P. software system will try to schedule all the activities needed to meet the master production schedule, while holding down work-in-process inventory. If this is infeasible, management must produce a new master schedule and generate another plan or find extra capacity.

4.5 Job Sequencing and Scheduling [7]

This is the most detailed part of the production control system. It is the most complex problem to solve and there are really no optimal solutions to the problem.

The situation is as follows:

At this point, a detailed plan exists, consisting of what components need to be made, when they need to be made, on which machines they are to be produced and in what quantities they are to be made. The task is now to make sure that the jobs are performed on the machines in the correct order and at the correct time so as to ensure that the performance criteria of the company is met.

The job sequencing problem can be stated as:

Given n jobs to be processed, each has a setup time, processing time and a due date. In order to be completed on time, each job is to be processed at several machines. It is required to sequence these jobs on the machines in order to optimize the performance criteria.

Some possible performance criteria are:

- Mean flow time in the shop
- Idle time of machines
- Mean lateness of jobs
- Mean earliness of jobs
- Mean queue time

- Percentage of jobs late

There are several factors that need to be taken into account when sequencing jobs. These include the number of jobs to be scheduled, the number of machines in the machine shop, the type of manufacturing layout (product or process layout), the manner in which the jobs will arrive (at constant intervals or intermittently) and also the criteria by which scheduling alternatives will be evaluated.

While algorithms exist for n jobs on one, two or three machines, there are no general solutions for n jobs on m machines. There are a few heuristic algorithms that present solutions to the problem although they do not guarantee the optimal solution. Two such algorithms are the Stinson-Smith algorithm and the Campbell algorithm.

The complexity of the situation increases greatly when the layout out of the plant is a job shop. Many organizations have resorted to using simulation techniques as research tools to find an optimal schedule. Alternatively, certain criteria are adopted by which to schedule all the jobs, such as 'first come, first served', 'earliest due date', 'least operational slack time'.

While no organization follows the above system of production to the letter, it is common to find many of the techniques listed above being used in most manufacturing organizations. While these techniques are not necessarily wasteful, they are in no way intended to be efficient. They simply produce a solution that ensures that enough parts are produced at the right time. With these techniques, come the potentially damaging attitudes towards inventory, scheduling, layout and material control. These attitudes have resulted in U. S. manufacturers becoming complacent about their ability to effectively compete with other producers in other nations.

5. JUST IN TIME TECHNOLOGIES

The Just In Time production philosophy is derived from three principles - the reduction of production costs, the elimination of waste and the recognition of workers' abilities [23]. Just In Time manufacturing strives to reduce work in process inventory, so that only the minimum number of parts needed are produced.

It is described as a demand pull system, i.e, when the demand for an item is arises, then and only then is the item produced. The system is based on the pulling action of Kanban, this is the Japanese name for a visual record or ticket. Kanban is the production control system used to ensure that the right amount of parts are made at the right time. In the Kanban system, parts or components are not produced until needed by the downstream work center.

Just In Time philosophy as it applies to physical manufacturing is made up of the following elements:

- Minimize work in process inventory
- Minimize fluctuations in work in process levels in order to simplify controls
- Minimize production instability by preventing transference of demand fluctuations from one part of the process to another
- Reduce defects - only one hundred percent quality is

acceptable.

There are many aspects that are necessary for successful Just In Time implementation. Detailed below are the more critical factors, though note that they are not necessarily presented in the order needed for successful implementation.

5.1 Focused Factory

This concept requires that the production system be specifically designed for a limited number and variety of production lines [34, 35]. This practice eliminates conflicts between the production needs of different products, in that it will help to reduce inventory and material handling, identify responsibility and broaden the span of control. The first task is to define the product line by market, function, parts used and by processes. Once the products have been defined, the equipment can be organized into cells. The cell is then product oriented rather than process oriented.

Once the cell is organized, the movement toward automation can commence. It is also vital that each process produces at the same rate each day for the given weekly demand. This ensures that equipment runs at the pace required for the production of that amount, not at the capacity of the machines and that it does not run on only certain days of the week to produce all the units needed for the week in the smallest amount of time. The first step toward automation occurs with the machine set to stop after each cycle, then the next stage is to have it automatically load. The final stage is that once the machine loads itself, it would then automatically initiate the next cycle.

Within this idea of a focused factory, it is important to realize a critical point. The present resources should be reorganized, that is, large capital investment is not required. Automation should be inexpensive. The people operating the machines should be the ones that control the pace that the machines operate at. Often, expensive machinery is run at maximum utilization because it has specific payback objectives and returns on investments to meet. Simple and flexible equipment that can be easily modified is vital and considerably more useful. Variability in production rates can be handled by adding or removing people from a particular cell. This arrangement also assists in improving quality, keeping closer control on production levels and inventory and a greater awareness by the employees of more elements of the operation. The cell layout should be as compact as possible so as to minimize transfer time and effort, storage and work in process inventory.

5.2 Group Technology

A very similar concept to the focused factory idea is group technology [7, 18]. In fact, group technology lends itself very well to the overall philosophy of Just In Time manufacturing. The idea behind group technology is simply to exploit the similarities in manufacturing techniques and design specifications of parts. In most cases a coding system is designed containing information on lot size, material, tooling requirements, form, tolerance, specifications, operation descriptions and general descriptions of the part that allow it to be assigned to a family of parts with similar manufacturing needs and design specifications.

Once these codes have been applied to as many of the parts as is feasible, the factory is reorganized into a cell layout structure. Each cell is then dedicated to making a certain group or family of parts, thus the machines can be dedicated to running a specific operation. This has the obvious benefits of reducing or even removing the set up time on the machine in question. With the reduction of set up time comes the ability to reduce lot sizes and establish a mixed model production schedule.

Note, that group technology codes are applied to as many of the parts as possible, however this does not mean that all the parts of the family can be made through the cell layout. Typically, there are still a few low volume parts with design specifications that cannot easily be reproduced by the machines in the cell. Thus, to produce these parts, a miniature version of a job shop layout is set up within close proximity to the cell. This enables these particular parts to be moved between the cell and these machines in the job shop as design specifications require.

5.3 Uniform Work Loads

The first step in levelling the production work load is to develop a production plan. The plan should consider all the demand - both actual and forecasted, as far into the future as the lead times require. The total demand is then divided by the number of working days in the periods contained in the production plan. This is now the daily production rate. Once the production rate is obtained, the same product mix is needed - this is the quantity of each part to be made per day. The objective in this task is to generate a level production rate and also generate a level mix per day. Thus lot sizes need to be cut to as small as possible - ideally one! In cutting lot sizes, production process problems will arise, due to the fact that less inventory will be available to act as a buffer against machine downtimes, inaccurate inventory records and product defects, these problems can then be solved as the process is improved. The aim of this is to generate even predictable demand [25].

5.4 Just In Time Delivery of Purchased Goods

Purchased parts should be delivered to the assembly area just in time for assembly into the finished product. This concept is deceptively simple - in order to achieve it, a strong relationship needs to exist between the company and the supplier. The supplier needs to be involved in the design specifications of the product so that they know how their product is used and what is expected of it in terms of quality and specifications. Supplier involvement is also required to ensure that the specifications are exactly what the company needs and what the supplier has the ability to produce. It is important to maintain these close relationships with the supplier, they should not feel threatened by the company's aim to produce on a Just In Time basis, in such a way as to wonder if they will lose the company as a customer, or that they need to invest in new unique equipment to produce exactly what is needed. The company need to be able to promise some kind of long term committment to the vendor in terms of purchasing from them as long as the vendor is able to supply the parts on a Just In Time basis.

The advantages of Just In Time delivery are many.

Production schedules are more easily met with a continuous supply of raw materials, inventory levels for raw materials and work in process are significantly lower, storage space required is reduced and greater flexibility in production is allowed. An important task that will ensure the success of this aspect, is to have 100 percent quality. Quality assurance people need to work with the suppliers so that the product, when it arrives at the receiving dock, has already been tested for quality and passed. The best way to obatin this is for the company to work with the supplier in the design stage of the product. The company should rely on the fact that the supplier has a greater knowledge of the product that it is supplying than the company will. It should ask their advice regarding the qualities of the product that it is purchasing from them so as to optimize the effectivness of the purchased product in the final product [7].

5.5 Minimum Set up Time

This is critical to the Just In Time philosophy. Many set ups are required to implement the uniform work load component [4]. Reducing the lot size will result in more frequent set ups while the output level is maintained. Unless the time to perform these set ups is reduced, the increase in down time will prove to be too costly.

The problem of lot sizing has been discussed within manufacturing circles for many years. It is widely seen as the reason for irregular demand. By reducing the lot size, the work load is levelled bringing with it all the benefits available to a uniform work load. Rather than struggle with the problem of optimizing the lot size so that the effect of set up time is minimized, Just In Time concentrates its' efforts on reducing the set up time itself. In this way, set up time will not play an important role in the process.

The first step in reducing set up is to document the elements involved in the set up operation. Information on the following areas should be obtained:

How many elements of set up are performed while the machine is still running the previous part? These are the external elements. All other elements are then known as internal elements - i.e., the machine has to be stopped in order to perform these elements.

Internal elements are things like loosening clamping devices, removing the old tool, placing the new tool and adjustments. External factors include location of tools and fixtures while the machine is still running the previous part.

Once this information has been gathered, the task is to try to convert the internal set up elements into external set up elements. Try to standardize tool heights and fastening methods - use preset fixtures, locking and location methods.

In this way, reduce or eliminate as much as possible any adjustments that need to be done. Adjustments often account for between 50 to 70 percent of the set up time.

Encourage accurate record keeping. This will help employees to keep track of where the tools are, when they were last sharpened, what the history of its problems are and what steps were taken to correct it. This information will not only help the employee obtain the necessary tooling for the next part but will also alert him to any possible problems with the tool that may affect the quality of the part.

The result of reducing set up time is that it will allow the lot size to be reduced. This, in turn allows the quality aspect of the process to be more closely monitored. If a defect were encountered, it would be easy to immediately find the reason for it and rectify the situation without producing large amounts of the defect.

5.6 Quality Control

A full Just In Time manufacturing system is a very sensitive process. If a defect or error occurs in some part of the process then it will affect the whole process and will do so almost immediately, the reason for this is the reduced lot sizes. If a small number of parts are produced and then passed on to the next work center and they are found to be defective, then the operator of that work center will quickly inform the previous operator of the error. Demand for the part is almost immediate from the next work center down stream, thus there needs to be a guarantee that the unit will reach this work center in perfect condition. For Just In Time to be successful, 100 percent defect free parts have to be available [25, 27]. Allowing any leeway in terms of level of quality expected will only serve to increase the costs of rework, material handling, storage, excess inventory, variation in production and customer service - all the things Just In Time manufacturing is trying to reduce!

Eighty-five percent of all defects occur because of process error. So in order to improve quality and reduce cost - the process needs to be thoroughly examined and monitored. Statistical process control is one technique that is commonly used to define the boundaries of performance of a specific process and indicate whether corrective action is needed. If at any time the boundaries are crossed, then the process can be stopped and the necessary adjustments made. Information from this technique is also used to determine when tooling needs to be resharpened or replaced, and to see if the material meets the quality requirements, etc.

In order to obtain 100 percent quality, several other departments need to be involved with the quality concept. The product should be designed so that it can be made easily within the predefined acceptable quality levels. The process, i.e., the machinery and operators, needs to be set up so that it can make the product without putting undue stress on process to maintain the quality levels. Quality control circles consisting of a mix of employees at all levels of the organization should be set up with the mission of trying to improve any part of the operation. It should be emphasized that these circles are not required to only look into improving the production operation. They are encouraged to examine all aspects of company operation - from production through to administration, looking for areas of possible improvement.

5.7 Preventive Maintenance

Due to the interdependence between work centers and the potential for a machine breakdown to cause an entire line to shut down, preventive maintenance is essential. Workers need to be knowledgeable about their machines' maintenance needs and be able to perform minor repairs themselves. To help in this aim, simple tooling and machinery should be stressed as the type of equipment desired for the plant. Also commonality and availability of tooling and equipment should be stressed. The more often an employee works with a certain tool or machine, the more familiar he will become with it - which would not only improve preventive maintenance skills but also improve the skill that he has in using the tool.

Records should be kept detailing the condition of tools and machinery and any problems occurring with it. On a regular basis, the records should be reviewed to look for any recurring problems so that the problem may then be addressed by the maintenance department and rectified.

5.8 Pull System

This aspect of Just In Time cannot be implemented until several other aspects (previously mentioned) have been implemented. The primary tool of this aspect is KanBan [33]. This is the Japanese name for a record or ticket which is used to authorize the production and or transfer of parts from one work center to another. The KanBan is initiated at the work center that needs the part and acts as a signal to the preceding work center to produce a specific number of parts. Without a KanBan to act as authorization for the part - it cannot be produced or transferred. The result of this is production based on the actual need of the item.

KanBan acts as a control and execution technique. It links various operations and the final assembly. It is a simple and visible technique that allows operators and supervisors to visibly determine the requirements.

A variety of KanBan systems have evolved. The two most common are the dual card and the single card.

The dual card system was developed by Toyota. It consists of withdrawal/conveyance kanBans and production kanBans. The production kanBans authorize the production of one standard container of parts at the preceding work center. The withdrawal kanBan authorizes the movement of a container of parts from an outgoing stock point to the succeeding in coming stock point.

The single card system is far simpler and more common. Here one card is used to control both the production and the conveyance of parts. As the container is emptied of parts at the preceding work center, the container and KanBan are returned to the preceding work center, thereby authorizing the production of another container of parts.

The main advantage of the dual card system is the extra level of control at the preceding work center, i.e., prioritizing the production.

The two card system is more appropriate in the job shop environment where several different parts are produced in a given work center. The single card system provides adequate control in environments where only a few parts are produced in a work center.

5.9 People Involvement and Commitment [11]

Again, this is another vital aspect of Just In Time implementation. An environment needs to be created where the employees feel trusted, that their work is respected and that they are trusted by management to produce quality units. This trust of the employees is manifested by management in several ways. The employees are split up into teams. Within these teams, each employee is encouraged to learn how to operate all the machines that each of the other team members operate. This type of cross training will increase their flexibility, which means that at times when that employees' particular machine is not running, they can operate another machine or cover for a team member if that member is absent. Encouraging employees to learn how to operate several machines, also aids in the maintenance of these machines. An employee who is familiar with how a machine operates is far more sensitive to what may go wrong and how to rectify it than a maintenance crew would be.

Employees are encouraged to contribute to the process improvement by offering any suggestions that they may have on how their operation could be improved or how the product could be improved. Many companies offer monetary incentive schemes to further encourage the employees in this area. There is the obvious possibility that employees may feel that if they suggest too many improvements then they may improve the process so much that their job becomes obsolete! To avoid this fear, management need to implement a program that will guarantee the employees' employment. This could entail promising lifetime employment after ten years of service with the company, or possibly a guarantee that after an employee becomes competent or certified on five different machines or skills, he will not be layed off. A great deal of care and thought needs to be put into implementing a program of this type regarding the costs and consequences of it.

As has been stated previously, the Just In Time method of manufacturing is a very sensitive system - if one machine begins to produce defective parts, then the whole production process is likely to be affected. Thus each employee that is operating a machine needs to be given the power to stop their machine as soon as a defective part is produced. This ability ensures that the quality of the product is maintained. This ability is called 'Autonomation'. It also means however, that for autonomation to work, the worker has to feel that he is trusted and respected enough to make the decision to stop his machine and consequently the whole process line. Should an employee stop his machine, then all the members of his team, provided they are not occupied, are encouraged to go to the machine in question and try to resolve the problem.

It is not only the machine operators in the company that need to be involved and committed to the philosophy. Management also need to show 100 percent commitment to the program. It is vital that they understand the concepts and philosophy of Just In Time manufacturing, so that they can establish the direction of the company and stay committed to it. This means placing very different priorities on manufacturing decision making tools such as manufacturing efficiencies, rate of investment and shipping budgets. They have to be prepared for many setbacks and problems and be ready to encourage their staff to keep persevering.

In discussing these techniques, it is apparent that with the exception of KanBan, Autonomation and perhaps Mixed Model Production, all of the techniques are very familiar to Western manufacturers. They are implemented just as frequently and the results that they offer, just as sought after. In fact, the desire to use some of these techniques is arguably stronger with conventional manufacturing than it would be for Just In Time manufacturing. An example of this is the Quality Control factor. With considerably larger lot sizes (at least several weeks of parts), the need for 100 percent defect free parts is greater than when the lot size is one. If there is going to be a quality problem with parts, it will have a more detrimental effect to the production flow when several weeks or months worth of parts are defective than if one part is defective. Similarly other techniques such as employee involvement, set up reduction, preventive maintenance, etc., are highly desirable in any manufacturing environment. So, why then are they more important for Just In Time implementation? The answer to this question lies in the different organizational structures of Just In Time manufacturing and conventional U. S. manufacturing.

Conventional manufacturing relies heavily on the staff management for making decision [7]. There will be departments for inventory control, production control, facilities planning, maintenance, and quality control. The line staff usually consists of a shop floor manager, foremen and the machine operators. The decisions of the line staff generally lie in the scheduling of jobs for the day. The operators themselves, have very little responsibility toward the overall production flow. Their task is to produce the parts in the desired quantities and quality.

Just In Time manufacturing adopts a very different management structure. Their staff management is minimal and their line organization takes much of the responsibility for production control, quality control, facility layout, maintenance, etc. Each operator is responsible for the machines he is operating at the time, in terms of maintenance, set up, the quality of the parts that are being produced on it, when the parts are produced. The responsibility for producing to the correct specifications in term of manufacturing and design rest entirely upon the shoulders of the operators.

The main aim of Just In Time philosophy is to be flexible - to be able to produce a perfect product in the minimum amount of time, without extensive production costs. This ability is what the customer is looking for in today's market. To do this, there have to be certain guarantees with regard to the manufacturing process. The machines must be reliable, the cycle time for the part must be minimized, there should be no doubt about the quality. Conventional manufacturing is, in many situations, not designed to be so flexible. While a quality product is still expected, no assurance is given to produce the part in the minimum amount of time. To try to produce one part in a minimum amount of time using conventional techniques would cause prohibitive production costs.

Just In Time manufacturing does not claim that the techniques it uses are different or better than those used in conventional manufacturing, only that they are critical to the philosophy. It is clear that many of these techniques originated in western manufacturing companies. The main proponents of 'Quality' were Deming and Juran, two Americans' that lectured all over the world on the subject. The Japanese simply have a different attitude to these factors.

6. METHODS OF RESEARCH

The research for this paper can be separated into three main areas :

1 - Documented case studies

2 - Plant visits

3 - A survey sent out to manufacturing companies

Information for the paper was primarily obtained from a survey sent out to the manufacturing companies. However it was important to examine the documentation of case studies in Just In Time implementation. This would give invaluable guidance in formatting and putting together the survey that was sent out to companies. Similarly, the visits to plants claiming to use Just In Time manufacturing were also important because they gave an indication of what factors were being used and how they were being implemented. Typically the implementation process was not as described in many of the definitive text books on Just In Time!

6.1 Documented Case Studies

As mentioned previously, the majority of the literature on Just In Time implementation has been published through the American Production and Inventory Control Society (A.P.I.C.S). A.P.I.C.S. initiated, as part of its annual international conference, a section of papers to be presented on Just In Time manufacturing - or as they named it 'Zero Inventories'. These papers covered a range of topics within Just In Time such as the type of production layout needed for Just In Time, how JIT can affect productivity, the importance of quality, how JIT affects distribution and how JIT can be merged with existing MRP systems. A significant amount of this section of the conference was given over to reporting case studies of organizations that had tried to implement Just In Time. To further encourage manufacturing companies to develop their knowledge of Just In Time, A.P.I.C.S. also set up a series of Zero Inventory Seminars. These seminars concentrated solely on Just In Time manufacturing with the aim of challenging manufacturers to look into this new method of production and to try to increase the efficiency of their production methods.

The majority of the case studies in the proceedings from the annual conference and the Zero Inventory seminar simply detailed the implementation program but gave no indication of which if any of the implementation factors were critical to the success of the program. In many of these cases, it was not possible to determine from the literature which factors were more important. They were useful in many instances for describing which trends in which types of shop (product or process) were being singled out for candidates of Just In

Time implementation. They also indicated which of the physical manufacturing techniques were used in the implementation. The majority of the implementation programs documentated began as small projects designed to improve the efficiency of a certain factor. For instance, a company may have initiated several projects to improve set up time, optimize the layout of the plant, produce to a mixed schedule and work with daily deliveries from the vendors. The documentation of this form describes the initial projects that were undertaken, however care must be taken not to automatically assume that these projects are the critical techniques of successful implementation. These projects may be initiated first, because the company already has some experience in these areas and want to make a clear and obvious improvement in the process that will show commitment to the labor force and or encourage management to support the program on a greater level.

Other information that the case study documentation gave is the results from the implementation in terms of improvement in set up time, inventory levels, space reductions, quality and lead time reduction. Also, many of the studies detail when the program was started, the reason for implementation, who initiated the program, where the first projects were started and what problems were encountered as a result of implementing these projects.

However much detail the studies give, they do not, in general, tend to indicate what percentage of the plant is now operating under Just In Time manufacturing techniques. It is typically, fairly easy to implement some small programs and to only concentrate on a few of the techniques such as set up time reduction, lead time reduction or cell layout. There were in fact several cases that indicated this. The company in its earnestness to report that it was operating on a Just In Time philosophy quickly implements a few programs and, having gained success in these areas, neglects to maintain the pressure to further implement the remaining techniques and factors. This shows perhaps a misunderstanding and lack of committment to the Just In Time philosophy on the part of management, in that they had failed to realize that true Just In Time manufacturing involved the implementation of all the techniques and philosophies, and that only when the full implementation was reached would the most improvement and benefits be received.

6.2 Plant Visits

Several plant visits were made to observe companies at different stages of implementing the Just In Time methodologies. These visits were extremely informative because they enabled the factors of this methodology to be visualized and it could also be seen how each factor interacted with the other techniques of the philosophy.

6.2.1 Fisher Controls, Marshalltown, Iowa

The first company that was visited was a local company in Marshallton, Iowa - Fisher Controls. They make a wide range of control valves for a varying range of industries, that include the oil and chemical industry, utility companies and the pharmaceutical companies. The company claimed to be operating on a Just In Time manufacturing philosophy. In fact they were at the very beginning of the road to operating on a Just In Time basis. They did however have some important programs in place and were able to run them very successfully.

Fisher Control operates in a large job shop environment, producing many thousands of different parts per week. The shop floor was divided into several sections with each section being run by a floor manager. The sections were set up according to the type of machines that were in the area, for instance one area consisted of numerically controlled machines, another of drills and presses. Orders were routed through the shop according to what operations were needed on them. The lot size was determined according to the forecast for the part and or the customer demand. Due to the shop floor layout being that of a job shop, there was an excessive amount of material handling and material storage, which was needed to ensure that all the machines were kept working at full capacity. Also lot sizes were kept as large as possible to reduce the effect of the set up time on the overall time per piece and also to reduce the cost of the set up time on the product standard cost. Although this company operated on a job shop philosophy, there were certain parts for which a standard process could be set up that allowed product standardization. For these parts, a process cell was installed. The company expected, through the use of this process cell, to be able to reduce the lot size to a bi-monthly amount, i.e., produce a two week supply at a time, they had previously produced a two month supply at a time. The process cell consisted of all the machinery needed to produce the family of parts in a small area of the shop floor. The material handling had been minimized, there were now only one or two operators who operated all the machines as opposed to the previous situation of one operator operating only one machine. These machines were also dedicated to doing only the one task needed to produce the part, thus there was a significant reduction of set up time. Also the queue time for each operation in the cell was significantly reduced, in some situations it was actually zero.

The company had also established some employee involvement and education programs, which were designed to encourage all employees to look for areas of improvements within the area that they worked. Then, they were invited to design a way of improving them and implement the recommendations once they had been improved. This was very similar to the quality circles concept stated in the texts. Another program that had been established was the 'Zero Defects' program. This program involved every member of the company going to school and learning about how the quality of the product was vital to the success of the company. It taught them to be conscious of the quality aspect of everything that they do. Weekly reports of scrap levels within the manufacturing environment were released so that the labor force were able to record their progress in this area. It should be emphasized that these two programs were applied to everybody that worked in the plant - from the plant manager, the secretarial staff, administration down to the maintenance and custodial staff.

The second plant visited was considerably more advanced in its Just In Time implementation program, they were also extremely proud of their success so far.

6.2.2 John Deere, Ottumwa, Iowa

John Deere of Ottumwa produce balers and golf and turf products. Their shop is operated on a product line basis, with a large assembly line at the end of their operation.

The first stage of the operation was called the primaries area. This area was the receiving docks for the raw material and where all first operations were carried out. Material was received usually every day from a bar metal vendor - Ryerson, Chicago. Due to close relations between Ryerson and Deere, the material was delivered on an as-needed basis and also by prior agreement it was shipped in the lot size needed for the particular order. Thus material was received, and because it was already in the correct lot size, could be transferred immediately to the first operation and recorded as Work In Process inventory. This also reduced significantly, the space needed for raw material storage to almost zero as well as the fact that there was now less paperwork involved in recording the material whereabouts. Deere were still using an M.R.P. system which generated the lot sizes of the material. Theoretically the only time that materials could move from one machine to another was if a scheduler released a card allowing this. However the work centers were close together, and the communications between the scheduler and the operators were so good that it was often the case that the material moved throughout the primaries area on an informal basis. The main concepts of Just In Time that were in use here, were the plant layout and the worker involvement in moving the material between each work center.

Once all the primary operations had been completed, the material was moved to the next schedulers' area by a material handler. The primaries area dealt with the initial simple operations such as cutting and pressing. The next area that the material was moved to was the machining area.

Here, much thought had been given to the layout of the area. The majority of the shop was set up in process cells, with one worker operating as many as eight machines in the cell. Each operator was given a considerable amount of responsibility with respect to the layout of the cell, the quality of the product that they turned out, and improvements that could be made with respect to set up time, lead time, material handling, etc. The operators were expected to keep their work areas clean and neat, they were shown how to monitor the quality of the product using control charts and were then required to be able to adjust the machinery should any defects arise in the product as a result of their operation. Quality at the source was emphasized, i.e., should a defect occur in their cell, then they were expected to rectify the machine and also remove the defect from the part if possible. Deere also initiated an incentive scheme to help encourage the employees to improve the efficiency of their work area as much as possible.

Other factors in this area included some dedicated machinery. This is machinery that is set up permanently for a particular task, thus set up time is eliminated. Deere tried to emphasize the utilization of simple flexible machinery that may not necessarily be state of the art, but could be dedicated so as to allow for a reduction in throughput time of the product. Also tool fixtures were standardized as much as possible so as to allow for quick and easy adjustments to a machine. To further reduce the throughput time, many of the purchased parts used in the areas were delivered directly to the process cell where they were needed rather than to a storage area.

Deere still employed schedulers in these areas, however their job specification was mainly that of identifying any so called 'hot' items and expediting them through the shop. They also have the power to move operators from one cell to another and are responsible for notifying the first process cell of the arrival of a new order, and of transferring finished parts to the next area.

The final area at John Deere was the assembly area. Here Just In Time manufacturing had been almost completely implemented. Practically all aspects of Just In Time could be seen in this phase. A mixed production schedule was in operation. The cell layout was again emphasized with each cell being placed close together to ease the communication ability between the operators. This enabled tighter controls on quality to be kept as well as lot sizes. The operator of a preceding cell was able to look to the next cell and observe how much of the product had been used. When it had been reduced to a certain level, he would automatically make some more of the product. To help with this, small storage bins were placed between the work centers for keeping the Work In Process inventory in clear view of all the operators and schedulers involved. As far as knowing which product to work on, the operators are simply given a schedule of the number of finished products that are to be made in that week. From this they are able to calculate themselves approximately how many of the parts that they work on, will be needed to complete the schedule.

Again it was obvious that the communication between operators was vital to the quality and smooth flow of the operation.

Deere continues to make use of older dedicated machinery and standardized tool fixtures to reduce set up time on the machines. All the tooling was designed specifically for the machine in question and was kept close to the machine that was to use it. The clearest example of this was a punch press that was fitted with several, different radii, punch beams - thus no set up time was needed at all for this piece of equipment. Tools were fixed back to back on swivel plates so that they could easily be used and set up. Also, robots were used in the welding area which again reduced the set up time.

Production of all the parts necessary for the final product were carried out around the assembly line, this reduced the material handling and transportation needed.

Clearly, for all of these aspects of production to be utilized successfully, the operators must feel convinced of the success of the system and be committed to it. They carry a major portion of the responsibility needed for this system to operate successfully. Each operator needs to be very conscientious with regard to the quality of the product, their skill level must be higher than the average level because they now have to operate more than one machine. They are also challenged to continually try to improve the process and take the initiative in developing new methods of production.

Another very crucial area that John Deere had identified as being vital to the successful implementation of Just In Time was employee involvement and commitment of top management. The production control department spent a considerable amount of time explaining to the labor force how Just In Time worked, how it would affect each employees job specification, the need for greater communication and understanding between the unions, employees and management. To strengthen the links between management and the labor force, a number of programs were set up. These included creativity awards, excellent employee award, company picnics and outings, incentive schemes, shop tours for any employee that wished to find out what other employees were doing, and daily and quarterly publications informing employees of Just In Time concepts and also the improvements that had been gained so far. The staff involved in implementing the program felt that it was vital for managment and labor to respect each others positions and realize that everyones' job was vital to getting the product out of the door in the required time, at the required cost and with the required level of quality.

When the production control department at John Deere decided to implement Just In Time methodologies, they first decided on areas within the plant that needed to be improved. The emphasis in ascertaining which areas needed to be improved was areas that could be improved at a low cost! Once these areas had been decided upon, a particular area of the plant was targetted for implementing some of these improvements. Deere chose the welding area and worked on the tooling and layout of the area. The tooling was connected to carousel configurations or set on swivels and the entire welding area was relocated closer to the assembly line. Once this project was successful, similar projects were implemented in other areas of the plant. Meanwhile on a plant-wide level, various employee involvement and education programs were implemented.

Just In Time implementation at John Deere has produced considerable benefits. At the time of the visit, they had no late orders and expected to produce on time for the immediate future, the cost of inventory had been reduced from approximately $60 million to $30 million. They expected to make a profit in the region of $20 million, this was an increase of $15 million in the last four years. Job satisfaction had increased, grievances and absenteeism had reduced by half.

6.3 The Survey

From the literature documenting Just In Time programs and the two plant visits to local manufacturing plants in Iowa, it became somewhat easier to visualize how the various Just In Time techniques were being implemented. The types of manufacturers that were implementing the methodologies and what existing factors from the previous manufacturing system affected how Just In Time was implemented.

Using the information already gathered from these previous two sources, a survey was compiled to be sent to the manufacturing companies that claimed successful Just In Time implementation. The aim of this survey was primarily to obtain information on their implementation program, however information was also sought regarding their previous manufacturing process as well as the type of products that they produced and in what type of environment.

The survey, (which can be found in Appendix I), consisted of ten questions. Each question was left fairly open ended and allowed the respondent to communicate their opinions at every available opportunity. The questions required the respondent to have a good knowledge of the implementation program that was used. It also required that they were one of the more critical personnel within that program, or that they were instrumental in deciding which factors of Just In Time manufacturing were of greater importance. The responses for many of the questions required the respondent to be subjective. In other words for many of the more crucial questions such as question 8, the answer depended very much on their view of the system and how it had been implemented in their company. To this end it was vital that the survey reached the most senior person in charge of the implementation program. It was estimated that the survey, if filled out completely, would take approximately thirty to forty-five minutes to answer. The fact that the survey would take so long to answer probably explained the somewhat disappointing response rate.

From the literature, the names of thirty companies were obtained, as well as the name of the director of the implementation program. Each company had presented several aspects of their implementation program for publication, and so were felt to have a working Just In Time system installed at their operation.

The survey was sent to these companies with a cover letter informing them of the aim of this research paper. Of the thirty surveys mailed, replies to ten were returned. Upon an examination of these responses to the survey, a second considerably condensed version of the survey (Appendix II) was mailed to those companies that had failed to return the first survey. This second survey was mailed approximately three months after the first survey. Twenty second surveys were mailed, six were returned.

The final response rate for the survey was a little over 53 percent. Due to the nature of the responses - subjective and qualitative, and also the small sample size, it was not possible to perform any statistical tests on the data. A summary of the responses was produced in tabular form, in order to derive any results or conclusions from the surveys.

7. RESULTS AND DISCUSSION

Table 7.1, on the following page summarizes the main results from the survey sent out to the production and manufacturing directors of the companies claiming successful Just In Time implementation.

Of the fourteen companies that provided applicable data to the survey, eight responded to the first more 'in-depth' survey and six companies responded to the second shortened version of the survey. Thirty surveys were sent out.

7.1 Evaluation of the Survey

The main reason for the survey was to try to discover the most important criteria for Just In Time manufacturing. Thus each respondent was asked to rate the criteria listed, or any other criteria that they felt were important, in order of importance. Obviously this was highly dependant on the respondent's experience with the Just In Time program. This fact should be kept in mind when evaluating the responses. In many cases, the respondent stated that all the listed criteria were vital to successful implementation, however they were able to evaluate and rate them - although the distinction in levels of importance for many of the criteria was a very fine one. This can be seen by the fact that several of the respondents rated only a few of the criteria

Table 7.1 Summary of the results of the survey

								Just In Time techniques that were used (rated according to importance from 1 down to 9)									
Company Name	Address	Contact	Type of Production Operation	Principal Products Produced	Previous Manufacturing Policies	When Implemented	Plant using J.I.T.	Set up Reduction	Cell Layout	Lot size Reduction	Kanban Scheduling	Quality Control	Autonomation	Employee Commitment	Stable Production Levels	Mixed Model Production	Comments
TOYOTA	Toyota Motor, U.S.A. 6375 Paramount Blvd. Long Beach, CA 90801	Edgar Manriqui	Repetitive Low Automation	Automobiles	M.R.P. Group technology Lot sizing	1983	100%	4	4	4	3	1	9	8	4	2	
HEWLETT-PACKARD	3404 East Harmony Rd Fort Collins Colorado, 80525	Steve Sponberg	Job shop Low volume High mix	Computer products	M.R.P. Assembly lines Lot sizing	1984	80%	2	5	3			4	1			rated only five techniques
OMARK Sporting Div.	605 Ord Dam Blvd. Oroville, CA 95965	Bruce Aldrich	Repetitive Low automation	Sporting equipment	Aggregate production plan	1982	90%	3	2	4	6	7	8	1	9	5	
HARLEY DAVIDSON	1425 Eden Rd. York, PA 17402	Patrick Keane	Repetitive Low automation	Motorcycles	M.R.P.	1982	95%	3	7	6	2	9	8	4	5	1	
LENNOX	P.O. Box 250 Marshalltown Iowa, 50158	Harry Brizzio	Repetitive Continuous High Volume Some automation	Air conditioners	M.R.P. Lot sizing Assembly lines Process layout	1986	75%	1	4	5	8	3	9	7	2	6	
OUTBOARD MARINE CORPORATION	100 Seahorse Dr. Waukegan, Il 60085	James Byard	Repetitive Low automation Continuuous		M.R.P. Group technology Cell layout	1986	20%	1	1	1	1	1	1	1	1	1	rated all as equally important
HEWLETT-PACKARD	3172 Porter Drive Palo Alto, CA 94304	John Kenfield	Continuous High Volume Medium Automation	Calculators Terminals Peripherals Electronic items	Lot size M.R.P. ABC analyses Job lot accounting	1982	80%	2	4	5	6	3	9	1	7	8	
NUMMI	4550 Fremont Blvd. Fremont, CA 94538	Paul Thompson	Repetitive Continuous High Volume	Automobiles	Company began using J.I.T. immediately.	1984	100%	5	7	7	1	1	9	1	1	5	
KAWASAKI	6600 N.W. 27th St. Lincoln, NE 68524	Doug Sutton	Repetitive Continuous High Volume Low automation	Jet Ski's Motor cycles	M.R.P. Lot sizing Shop floor control	1979	100%	1	5		4	2		None !!		2	Did have strong management committment
HEWLETT-PACKARD	P.O. Box 15 Boise, Idaho 83707	John White	Repetitive Low Volume	Analytical Insts Large Computers	Lot size M.R.P.	1982	70%	4	2	4	6	3	9	1	7	7	
WESTINGHOUSE	BOX 1693 Baltimore, MD 21203	J.P. Kelleher	Job shop Low Volume	Electronic Defense	Lot size M.R.P.	1982	25%					2		1	3	4	
JOHN DEERE	John Deere Rd. Moline, IL 61265	Frank Becker	Repetitive Varying degrees of Automation Continuous Job shop	Agricultural and Turf products	Lot size M.R.P. ABC analyses Group technology	1980	25% - 95%	2	2	2	2	2	2	1	2	2	All techniques are critical, but especially employee commitment
IBM	1000 Westchester Avenu White Plains, NY 10604	Vinay Sohoni	High Automation Repetitive High volume	Computer products	Lot sizing M.R.P. Group technology	1984	75%	2		5	3	3		1	5	5	
GENERAL ELECTRIC	1285 Boston Avenue Bridgeport, CT 06601	E.V. Spurgeon	Repetitive Low automation	Appliance motors	Assembly lines Lot sizing	1985		6	3	2	4	5		1	7	Already in use	

Footnote:

Replies to the survey were also received from 3M and Black and Decker. However, the material that they supplied proved not to be valid for this paper.

and stated that these were the more important ones but that the other techniques should in no way be ignored. Other respondents applied equal ratings to several criteria implying that these factors had all been equally important in their own implementation program.

Another difficulty that some of the respondents had in rating the factors is that many of the concepts of Just In Time are interrelated. For example, a lot size reduction program cannot be implemented if a set up reduction program has not also been started, otherwise the only result of lot size reduction will be to increase the down time of the machine and hence raise the manufacturing costs. Similarly stable production levels can be obtained without a mixed model production schedule and lot size reduction programs. This situation appears to resemble the 'chicken and the egg' idea - which comes first?

As stated, Table 7.1 details the overall results of the survey. Table 7.2 lists the top three techniques in the companys' implementation program. This table was developed because of the fact that several respondents failed to rate all the criteria on the list and also because some respondents applied equal rating to the some of the factors. However, twelve of the fourteen respondents did apply ratings to the top three factors. It was felt that there was sufficient evidence from the survey results to obtain the three most important factors.

7.2 Results

Table 7.2 shows that employee commitment is clearly the most important factor in successful Just In Time implementation. Sixty-four percent of the responses believed that without the commitment from the employees, the program would fail. Throughout all but one of the companies surveyed, the involvement, education and commitment of the employees was vital to their program. Kawasaki stated that they implemented their Just In Time program with no worker involvement whatsoever! They did state, however that management were heavily committed to the program. So if the definition of employee commitment includes the attitude of management and their involvement then the response rate of employee commitment is 71 percent.

The remaining factors were a little more difficult to distinguish as to their importance to a Just In Time program. Of those companies that applied ratings to the factors, 33 percent claimed that set up reduction was the second most important factor, 22 percent claimed that cell layout was the next most important factor, while twenty-two percent claimed that quality control was the more important factor. The

Table 7.2 The top three techniques used in implementation by companies

Company Name	First Factor	Second Factor	Third Factor
TOYOTA	Quality control	Mixed models	Kanban scheduling
HEWLETT-PACKARD	Employee commitment	Set up reduction	Lot size reduction
OMARK Sporting Div.	Employee commitment	Cell layout	Set up reduction
HARLEY DAVIDSON	Mixed models	Kanban scheduling	Set up reduction
LENNOX	Set up reduction	Stable Production Levels	Quality control
OUTBOARD MARINE CORPORATION	----- Rated all criteria as equally important -----		
HEWLETT-PACKARD	Employee commitment	Set up reduction	Quality control
NUMMI	Quality control Kanban scheduling Employee commitment Stable production		
KAWASAKI	Set up reduction	Quality control	Mixed models
HEWLETT-PACKARD	Employee commitment	Cell layout	Quality control
WESTINGHOUSE	Employee commitment	Quality control	Stable production levels
JOHN DEERE	Employee commitment	---- Remaining criteria ---- rated equally	
IBM	Employee commitment	Set up reduction	Kanban Scheduling Quality control
GENERAL ELECTRIC	Employee commitment	Lot size reduction	Cell layout
Percent Response	64% Employee com. 14% Quality control 14% Set up reduction 7% Mixed models	33% Set up 22% Q.C. 22% Cell layout	44% Q.C. 22% Set up

remaining percentage was divided equally between mixed model production, stable production levels, lot size reduction and Kanban scheduling.

It appears that there is no clear agreement or distinction between the factors. In an attempt to obtain some differentiation between these factors, other responses from the survey were also included such as the percentage of the plant that is currently operating under Just In Time philosophies and also when the program was started. The information regarding when the program was started gave some indication as to the amount of experience the company has had with the concepts.

To this end, Table 7.3 lists the companies that stated cell layout, set up reduction or quality control was the second most important factor. Also stated are the dates that the company started their Just In Time programs, the percentage of the plant that is running under Just In Time and also the first choice technique of the companies.

From this table, the company with the most experience and 100 percent plant wide use of Just In Time is Kawasaki. Their second choice factor is Quality Control, however their first choice factor was set up reduction! This tends to lend more credibility to set up reduction being the next most important factor. Hewlett Packard (Fort Collins), whose

Table 7.3 Companies that rated set up reduction and quality control in the top three positions

Company Name	First Factor	Second Factor	Third Factor	When Implemented	Percentage of Plant using J.I.T.
TOYOTA	Quality control	Mixed models	Kanban scheduling	1983	100%
HEWLETT-PACKARD	Employee commitment	Set up reduction	Lot size reduction	1984	80%
OMARK Sporting Div.	Employee commitment	Cell layout	Set up reduction	1982	90%
LENNOX	Set up reduction	Stable Production Levels	Quality control	1986	75%
HEWLETT-PACKARD	Employee commitment	Set up reduction	Quality control	1982	80%
NUMMI	Quality control Kanban scheduling Employee commitment Stable production			1984	100%
KAWASAKI	Set up reduction	Quality control	Mixed models	1979	100%
HEWLETT-PACKARD	Employee commitment	Cell layout	Quality control	1982	70%
WESTINGHOUSE	Employee commitment	Quality control	Stable production levels	1982	25%
IBM	Employee commitment	Set up reduction	Kanban Scheduling Quality control	1984	75%

program is six years old and has 80 percent of the plant operating under the program, favor set up reduction, as does IBM with 75 percent implementation and a six year old program. Omark, which has the second oldest program at eight years and 90 percent implementation, favors cell layout as the second most important factor but puts set up reduction as the third choice. Lennox also place set up reduction (first) above quality control (third) in their evaluation. While the evidence is far from conclusive, there is a trend towards set up reduction being the second most important factor in Just In Time implementation.

By a similar process of reasoning as that used to obtain the second most important factor, quality control was decided upon as the third critical factor. This factor comes close to being the second factor as it appears as the first choice for both Toyota U. S.A. and New United Motor Manufacturing (which is a joint partnership between General Motors and Toyota to produce the Toyota Corolla and the new GM GEO models). Both of these companies have 100 percent Just In Time implementation, and a wealth of knowledge and experience in implementing the Just In Time concepts due to the close links to Toyota Japan.

Thus, it appears that the three most critical factors (in order of importance) necessary for Just In Time implementation are :

1 - Employee commitment

2 - Set up reduction

3 - Quality control

Again it should be emphasized that the second and third factors are not easily differentiable from each other or from the remaining factors such as cell layout, lot size reduction, preventive maintenance, mixed model production, stable production levels, Kanban sequencing and scheduling and autonomation.

While ascertaining the critical factors for implementation is important, it is also equally as important to obtain some idea of the time schedule for when each of the factors should be implemented. And in what magnitude with respect to the size of the plant should the factors be initiated? For example, should the program be initiated on a plant wide basis immediately or should a small area of the plant be selected for a trial project and the results studied before a full fledged program is set up? Also, what time span should the project run over, what type of results are expected and when should the results be apparent? How much time should be allowed between the implementation of one technique and the next technique?

For the majority of these questions, the answers will be entirely dependent on the type and structure of plant (product or process layout, low or high automation) that the program is being implemented in and the level of communications between the labor force and management. Other factors that will dictate how quickly the program can be implemented include the complexity of the design of the product, the plant layout, the ease with which the machinery can be moved and manipulated toward customization, the relationship with the vendors in delivering parts on a Just In Time basis.

Inclusion of these factors into an attempt to propose a plan for implementing Just In Time means that the plan will have to become highly customized towards the company that it is developed for. It would be very difficult to propose a generic plan that would be equally applicable in all areas to all manufacturing companies. Just as the manufacturing process for a product is unique, so should be the implementation program for plant.

The responses given regarding the implementation plans that the companies' surveyed used, verify this fact of very individualistic implementation plans. Answers given show that one plan involved a plant wide conversion plan to Just In Time philosophy such as was the case with New United Motors. While many other companies begin with an employee education program to inform the labor force and management of what the philosophies involve, from there on the plans differ according to the companies' area of expertise. The majority of the companies that implemented Just In Time do move on, after initiating the employee commitment and education program, to selecting a specific area to test certain Just In Time concepts. This philosophy is known as islands of Just In Time. As one island operates successfully on a Just In Time basis, another area of the plant is converted to Just In Time. Eventually all areas of the plant will be converted.

This was the implementation program used by John Deere (Ottumwa works). The welding area was picked as the first area to convert. Employees were encouraged to try to develop a better layout of the area and also to reduce the set up time. Once this had been accomplished, the final assembly area was concentrated on. Thus at this stage, the John Deere plant is at varying levels of implementation - the primary area has reached a level of 25 percent implementation, the final assembly is 90 percent Just In Time operated, while there are still areas such as the plastic molding area that none of the Just In Time philosophies have been applied to.

It has been shown that any implementation plan must be configured to the plant that it is developed for. However, a general strategy for implementing Just In Time in a job shop environment is proposed in the following chapter.

8. IMPLEMENTATION STRATEGY FOR JUST IN TIME MANUFACTURING

Just In Time manufacturing is often separated into three areas - Employee Involvement, Total Quality Control and Waste Elimination. It is this third area of JIT manufacturing that this chapter concentrates on. The aim is to develop a strategy that describes the procedure needed to implement this philosophy in a U.S. manufacturing environment. This strategy will define the specific manufacturing techniques needed, and will also detail how each of these techniques are integrated to produce a balanced flexible production line.

The survey results do not conclusively show that any particular manufacturing technique is clearly the more important. There is some indication, however, that set up reduction and cell layout are more important. However it would be extremely unwise to ignore any other manufacturing techniques such as Kanban, lot size reduction, preventive maintenance, mixed model production, etc. in an implementation program.

If the results table is limited to show priorities for manufacturing techniques only, then it would appear as Table 8.1. Here, we see that cell layout and set up reduction are important programs but other programs that also should be implemented are the mixed model production program and the Kanban system.

Table 8.1 Table to show the priorities for only the manufacturing techniques

Company Name	Set up Reduction	Cell Layout	Lot size Reduction	Kanban Scheduling	Autonomation	Stable Production Levels	Mixed Model Production
	Just In Time techniques that were used (rated according to importance from 1 down to 9)						
TOYOTA	3	3	3	2	7	3	1
HEWLETT-PACKARD	1	4	2		3		
OMARK Sporting Div.	2	1	3	5	6	7	4
HARLEY DAVIDSON	3	6	5	2	7	4	1
LENNOX	1	3	4	6	7	2	5
OUTBOARD MARINE CORPORATION	1	1	1	1	1	1	1
HEWLETT-PACKARD	1	2	3	4	7	5	6
NUMMI	3	5	5	1	7	1	3
KAWASAKI	1	4		3			2
HEWLETT-PACKARD	2	1	2	4	7	5	5
WESTINGHOUSE						1	2
JOHN DEERE	2	2	2	2	2	2	2
IBM	1		3	2		3	5
GENERAL ELECTRIC	4	2	1	3		5	Already in use

Perhaps, in an attempt to obtain a better feel for which of the factors are critical, it would be more beneficial to ask 'what are the factors that left un-implemented, mean that the J.I.T. implementation program will fail? '

To answer this question, one must first decide on what the aim of Just In Time manufacturing is, and what does this mean in terms of the manufacturing process?

Just In Time manufacturing means to produce the right amount of the product in the right time period, with 100 percent quality. To be able to meet this aim, a manufacturing process must be FLEXIBLE so as to meet the altering levels of demand. This entails being able to adjust the capacity of the plant in terms of manpower and machine utilization, it entails being able to make these adjustments quickly and with a minimum amount of effort and change to the plant organization [16].

To maintain this type of flexibility to allow for varying demand, we must be able to reduce our lot sizes to very small quantities. In order to do this, one must first reduce the set up times on the machines. With reduced lot sizes, one is then able to schedule mixed model production. Another factor that is necessary for a successful reduction of lot sizes, is that the layout of the plant is moved into a cellular mode. If the machines were not laid out in this fashion, then the amount of material handling would increase dramatically as small lot sizes were constantly moved throughout the shop floor. This would not only increase the cost of the part but also create problems with the increased amount of traffic that was operating in the shop. Another reason for the cellular layout is quality. By placing the machines that carry out the work on the part adjacently, any quality problem that arises is quickly noticed due to the small lot sizes. It also becomes significantly easier and quicker to find the reason for the defects and rectify it because all the contributing machines are in close proximity to each other.

Set up reduction and cell layout seem to be the prerequisites for many of the other programs to be implemented in an effective and efficient way, such as a stable schedule, Kanban, mixed model production and small lot production. Therefore, these two factors should be among the first to be initiated in a Just In Time implementation program from a manufacturing techniques point of view. Following these factors, efforts should be made to initiate a lot sizing reduction program and then mixed model production and Kanban.

One final extremely significant factor that needs to be taken into account before any implementation is initiated is the type of shop that it will be applied to. Just In Time manufacturing was primarily developed for the high volume, repetitive manufacturing industry, rather than the low volume, job shop industry. However, it has been shown by a few job shop manufacturers that Just In Time can be as readily applied as it has been in repetitive industries [14, 6]. Of these job shop manufacturers, four of them - IBM, John Deere, Toyota and Outboard Marine Corp, stress the importance of Group Technology. John Deere go as far to say in the description of their implementation program that Group Technology was the key to the success of their implementation program! Thus for implementing Just In Time manufacturing in a job shop environment successfully, Group Technology appears to be vital.

Given the preceding thoughts and comments, a strategy for Just In Time implementation follows. As has been commented the hardest environment to implement Just In Time in, is the job shop environment. Thus, the strategy will assume that the shop to be converted is a job shop and it will detail the necessary factors in converting it to a Just In Time manufacturing process. Also, due to the previously agreed importance of Employee commitment and Quality control, this strategy will concentrate on implementing the actual manufacturing techniques, with only a passing mention of quality and commitment at the appropriate times. It is assumed that these programs, due to their importance and justification in their own right, will be implemented separately and prior to the J.I.T. manufacturing technique implementation.

A conventional job shop has a layout as in Figure 8.1. Machines of similar function are grouped together in the same area [32]. Thus, it is common to find all the milling machines in one area, all the turning machines next to them and all the grinding machines in another area, etc. Parts move through the shop in large lot sizes - possibly several days supply or even several months supply at a time. The lot size is determined by the demand, the set up time and cost of the set up for the machine that the part will be run on, the greater the set up time and therefore cost, the larger the lot size so as to reduce this cost per part. Due to these large lot sizes, the lead time between operations is likely to be several days. There will also be a large amount of material handling as the lot will be transported to different areas of the shop depending on which machines are needed to perform the operations. There will also be large storage areas in and around the work centers allowing parts to be stored by the machine that they are next scheduled to be processed on. It is not uncommon for several orders to be waiting in this area if the machine is running behind schedule.

With each order there is a shop pack. The shop pack will contain information for the order regarding quantity,

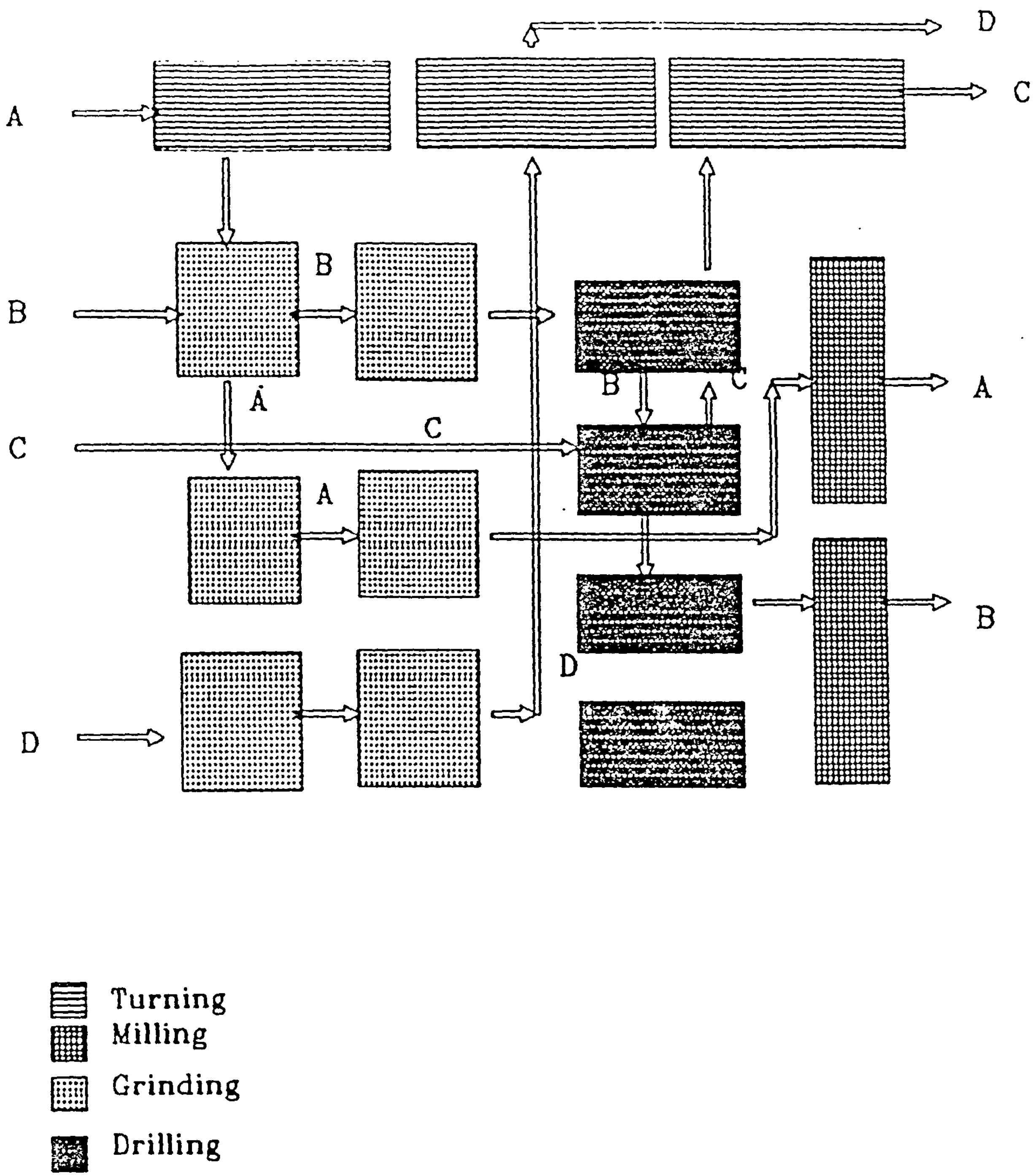

Figure 8.1 Movement of parts (A,B,C,D) through a job shop

due date, material to be used, a routing sheet and specifications for the operators on how to make the part and what dimensions are needed. Other paperwork that is issued to the shop floor is the dispatch list and move tags which signify when an order has been processed on the machine and can be moved to the next machine. The dispatch list contains the orders that have been scheduled to the machine, signifying which have been released to the shop floor and the priority assigned to them with regard to urgency of completion. It also notes other orders that have the same set up specifications, thus allowing the operator to use his judgement in choosing to run an order that is not necessarily first on the list but does use the same set up that they currently have on their machine.

8.1 Stage 1 of JIT implementation

8.1.1 Group Technology

A coding scheme needs to be established that will give all the necessary information needed to make the part. The code typically contains thirty digits which deal with form, tolerance, lot size, material, overall lengths, operation description and the general operations required for the part including the tooling requirements. It is usual for some part of the code to describe the family that the part comes from. That is, as many of the parts as possible are grouped into families - all the parts in one family would have similar specifications in terms of manufacturing requirements. This coding is applied to as many of the parts as is feasible.

This concept sounds relatively simple, however it is not uncommon when deriving the codes to find that there are many variations in the system in the area of routings, tolerances and specifications. There are usually many process plans in existence for each part. This is due mainly to the way in which the routings and process plans are developed. The analysts developing these plans are usually people who have demonstrated a level of practical expertise in a particular area of the machine shop. These analysts will naturally run the part through the area of the shop that they are most familiar with. Few people would challenge the judgement of an ex-engine lathe analyst with twenty years of experience on the machine. As new tooling concepts and machine innovations arise, an effort is made to update the plans that could benefit from it. However, it is often impossible to ensure that all the relevant plans are updated. So a variety of plans are likely to exist for a single product. A concerted effort must be made to standardize these plans not only for the sake of obtaining standardized parts but also in an attempt to standardize the tooling requirements. With the reduction of process plans, fewer tooling packages will be required. An effort should then be made to define and record these standard tooling packages.

8.2 Stage 2 of JIT implementation

8.2.1 Cell layout

Having standardized the process plans and tooling packages, the final step to group technology is to reorganize the factory layout. The most advanced application is to create manufacturing cells (Figure 8.2). A cell is a collection of machine tools and material handling equipment grouped to process one or several of the part families. Preferably, parts are completed within one cell. This level of reorganization involves separating each area of machinery into cell areas, with each area consisting of the machines necessary to perform all the operations necessary to complete the production of the part or family of parts. This means that the machines are dedicated to the production of a particular part or family of parts. The parts that are able to be produced through the cell are prime candidates for Just In Time manufacturing. The advantages of this type of cellular layout are many.

Pieces can be produced and passed onto the next machine

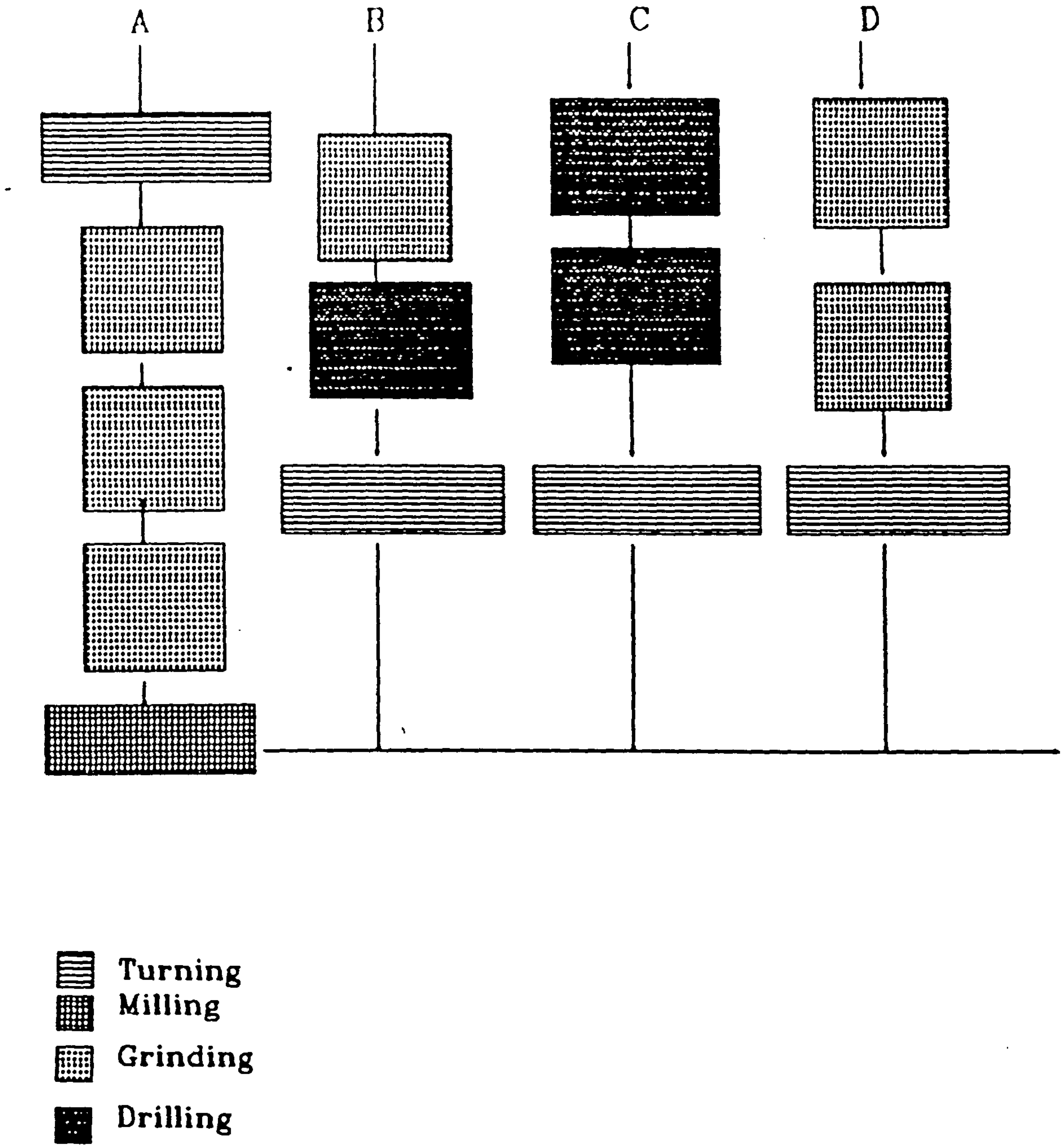

Figure 8.2 Movement of parts (A,B,C,D) through a cell shop

as soon as they are finished on the first machine - thus effectively reducing the lot size to one. There will be a significant reduction in the amount of material handling because the machines are next to each other. The lead time for the order is reduced to a matter of hours rather than days, also the need for storage space between the machine is removed because parts do not need to wait. With the implementation of these cells, there is also a reduction in the amount of paperwork that is released to the floor. There is now no need for details on the process routing, the specifications on tooling and setup and the specifications on size. The move authorization tags also become redundant. All of these factors are predetermined by the nature of the cell.

The percentage of the plant that is converted into cells is dependent upon the number of families and the level of variance between the parts within the family. It would be very simple to set up cells for EACH part, however this would require an inordinate amount of equipment and space.

There will typically be some parts within the family that are low volume and have design specifications that cause them to need special operations that cannot be handled within the cell. These parts are produced in small work centers set up in a job shop layout, and are not good candidates to be produced on a Just In Time basis.

8.2.2 Set up Reduction

It is preferable that a cell is able to produce a family of parts. With regard to implementing Just In Time, one particular family of products should be chosen that can be converted to cellular manufacturing. In order to run a family of parts through a cell, a program of set up reduction running concurrently with the cell layout program needs to be implemented. If the set up program is not initiated, the benefits from cellular layout will be minimized due to the fact that there will still be considerable changeover time between the orders.

As mentioned in Chapter 5, the set up reduction program can be approached in the following way:

1- Separate the internal setup from the external setup

2- Convert as much of the internal setup to external setup as possible

3- Eliminate the adjustment process

4- Abolish the set up itself.

There are several techniques that can be used to apply these concepts [21].

a) Standardize the external set up. All operations for preparing the dies, tools and materials should be standardized and recorded for all operators to see.

b) Standardize only the equipment that the machine needs. It would be expensive and time consuming to standardize all the equipment even if the machine in question does not require it.

c) Use quick fasteners. The standard nut and bolt used to fasten equipment is relatively inefficient, in that it only tightens at the last turn of the nut and loosens at the first turn. A more efficient fastener would be one that only requires a single turning to fasten it.

d) Use a supplementary tool. If it takes a long time to attach a tool, then attach it to a supplementary tool that can easily be inserted into the machine as part of an internal set up.

e) Use parallel operators. If a machine requires a long set up, then train several operators in how to set it up or initiate specific set up specialist jobs to perform the task.

f) Use a mechanical set up. Build electronically operated mechanisms to adjust various tools and machinery.

g) Use dedicated machinery. Rather than purchase expensive large volume machinery, buy smaller inexpensive machinery that can be permanently configured to perform an operation in a cell.

With the establishment of set up reduction programs in each cell, it certainly becomes possible to reduce the lot sizes of parts and also to have one cell run a family of parts without incurring major time delays in changing over from one order to the next.

At the beginning of this chapter, it was stated that flexibility in terms of production volume was the key to Just In Time production. It is with this in mind that Just In Time manufacturing takes cell layout philosophy one stage further. The cell layout and reduction of set up times have increased the flexibility of machines, the aim is now to increase the flexibility of the operators. This is brought about by the physical layout of the cell and the number of operators assigned to each cell.

Traditional cell layouts have often taken the form of dedicated production lines as Figure 8.2. Just In Time tends to arrange the cells in formats as shown in Figure 8.3 and Figure 8.4. The cell is organized over as small an area as possible.

Traditional cellular manufacturing is usually laid out in a long straight line with lots of space between each machine. There is usually one operator for each machine in the cell and some type of automated material handling system linking the machines. With this layout, every machine must be producing constantly to keep all the operators busy. Also, much of the space between the machines is filled with work in process inventory, which restricts the view and access that each worker has to the cell and his fellow operators. With the cell laid out in this format, it is very hard to have any control over the production rate, in most cases it is fixed at the capacity of the machine with the lowest capacity (this machine is effectively the bottleneck operation of the cell).

With Just In Time cells, the emphasis is on making the cell produce at the rate required by the demand NOT by the capacity of the machines within the cell [11]. This means that if the demand for the product is less than the minimum capacity of the machines, then the machines in the cell should not operate at full capacity. While it is obviously possible to reduce the production rate of the machine, the problem arises that the operators, at times, having nothing to do. This is obviously a wasteful use of a valuable resource. Just In Time cells resolve this problem by cross training their operators to operate several different machines. Thus for each cell, there will usually be less operators assigned to it than there are machines. Each operator would run at least one of the machines in the cell. However, for an operator to run more than one machine, they must have easy access to the machines that they are assigned to operate. This final requirement is virtually impossible in a straight line layout, especially if there are stock piles of work in process inventory between each machine which

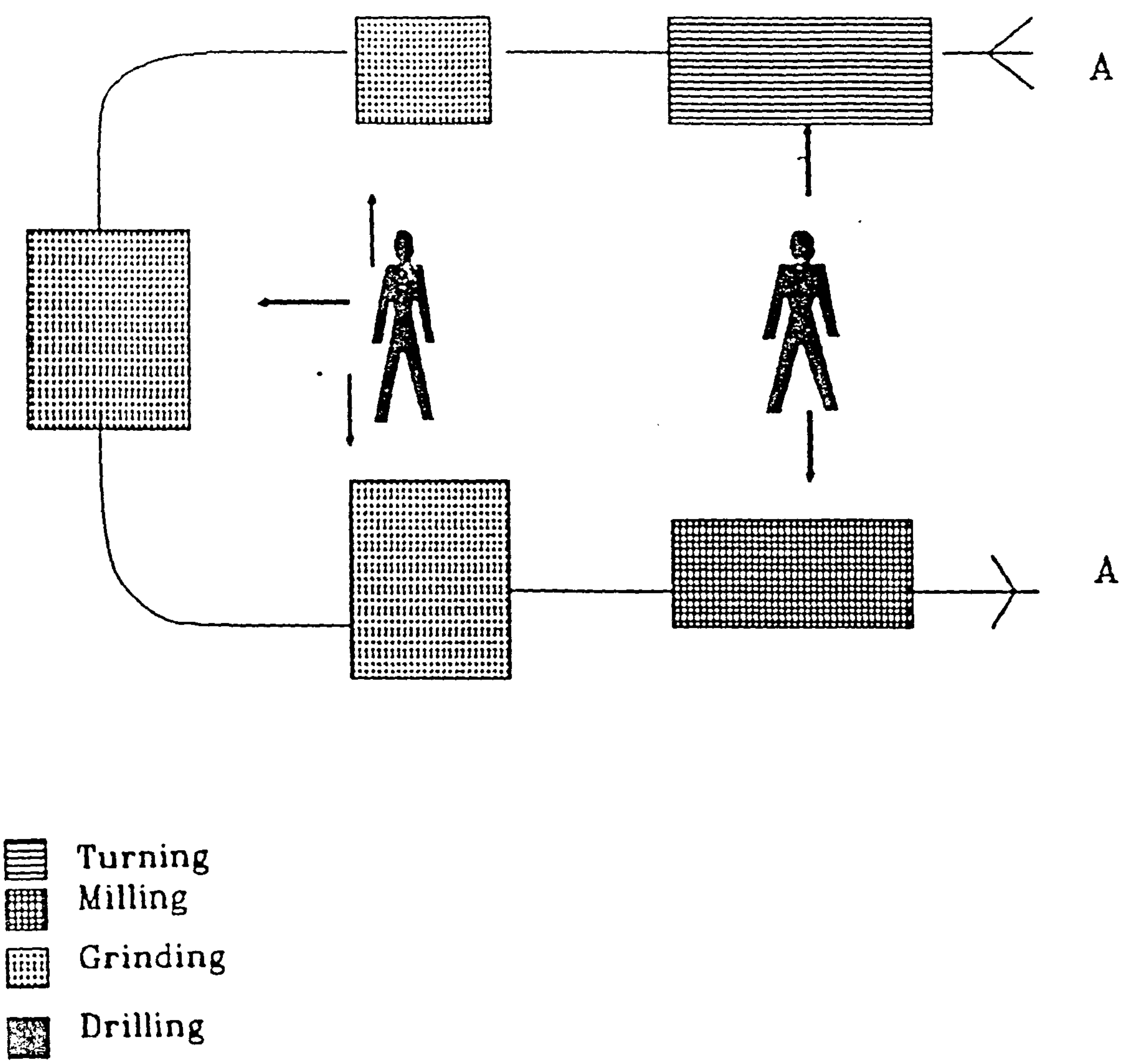

Figure 8.3 Movement of part A through a U-form cell

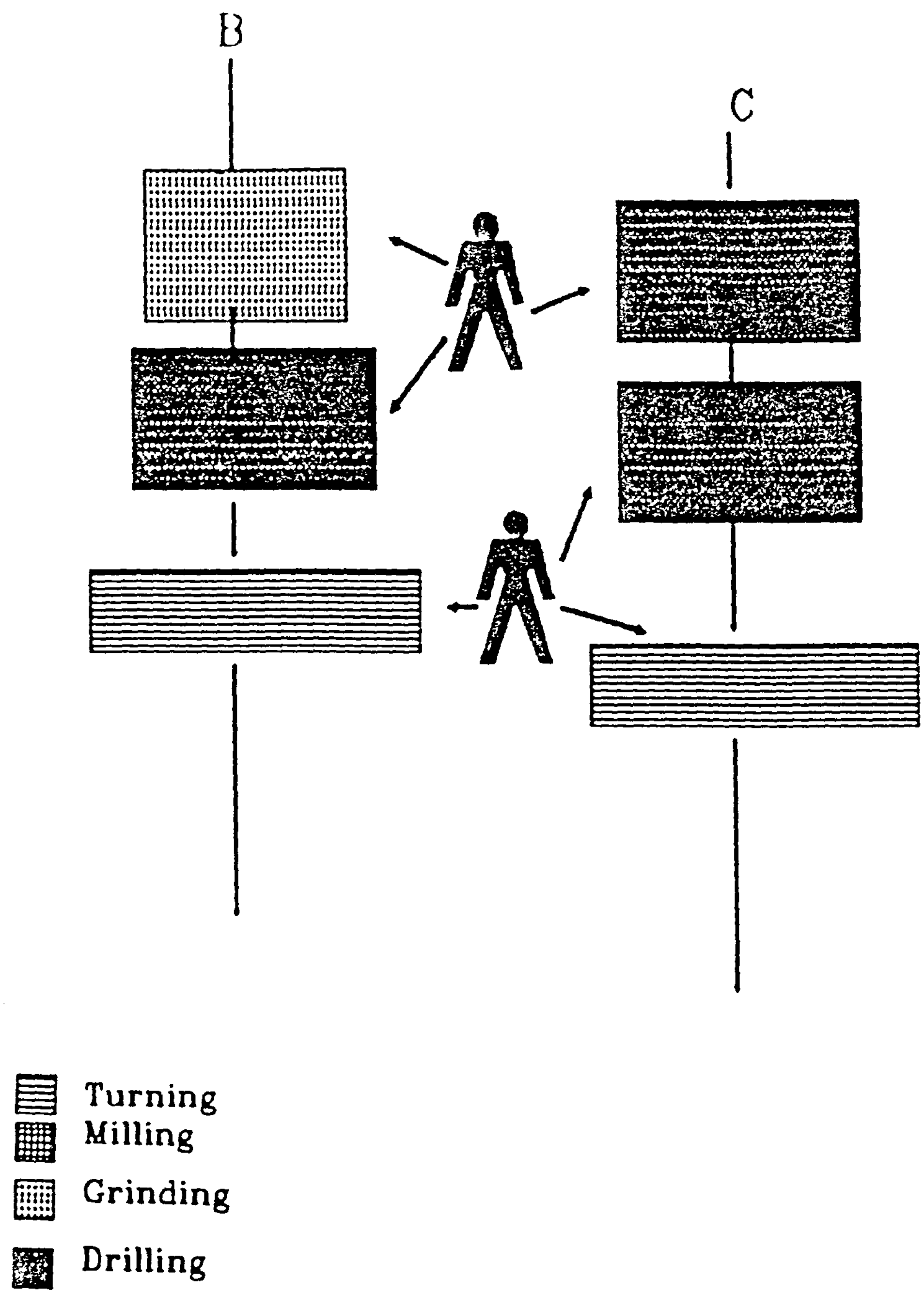

Figure 8.4 Movement of parts B and C through a parallel cell

now there are no large work in process inventories that other machines can be kept busy with. Here also, the autonomation technique should be made available. It should be emphasized to the operators that it is better to stop the production in the cell, rather than produce any more defective parts.

8.3 Stage 3 of JIT implementation

Once this flexibility between operators and machinery has been obtained, the next stage of Just In Time implementation can occur within the cell. This is the initiation of a lot size reduction program and mixed model production. If lot sizes are reduced, then it is a simple matter to implement a mixed production schedule. Finally, the KanBan or demand pull system should be implemented. Within the cell, there is less of a need for a formal ticket system, rather operators can visually check to see if the next machine in the cell needs parts - another reason to maintain a clean and clear work space!

The advantages of KanBan come into play, when the flow between the cells is linked [27]. Kanban cards are used between the cells to authorize the production of parts. The importance of flexible workers increases further as more of obstruct not only the workers mobility but also his field of vision. If the operator is unable to see the machine, then he is also unable to tell if there is a part waiting to be worked on there.

For this reason, Just In Time cells are often shaped in a U-form (Figure 8.3), with very little storage room between each machine. An alternative layout is to place two straight line layouts parallel to each other (Figure 8.4), and assign an operator to work on both lines. With these layouts, it is very easy to vary the number of workers as the demand varies. If the demand for the product falls, the number of workers assigned to the cell is reduced and the number of machines that each operator operates increases. Because the machines are close together and there are no obstructions within the cell, the operator is easily able to operate several machines at one time. Now, even though the machines may not necessarily operate at full capacity, the operators' time will be fully utilized. Another advantage of this layout manifests itself when a quality problem arises within the cell. Any worker within the cell, that is available, is able to go to the machine that is causing the defects and try to repair it. When this occurs, it is important to repair the machine with a permanent repair rather than some temporary measure. The reliability of machines in this type of manufacturing environment is more critical than ever because

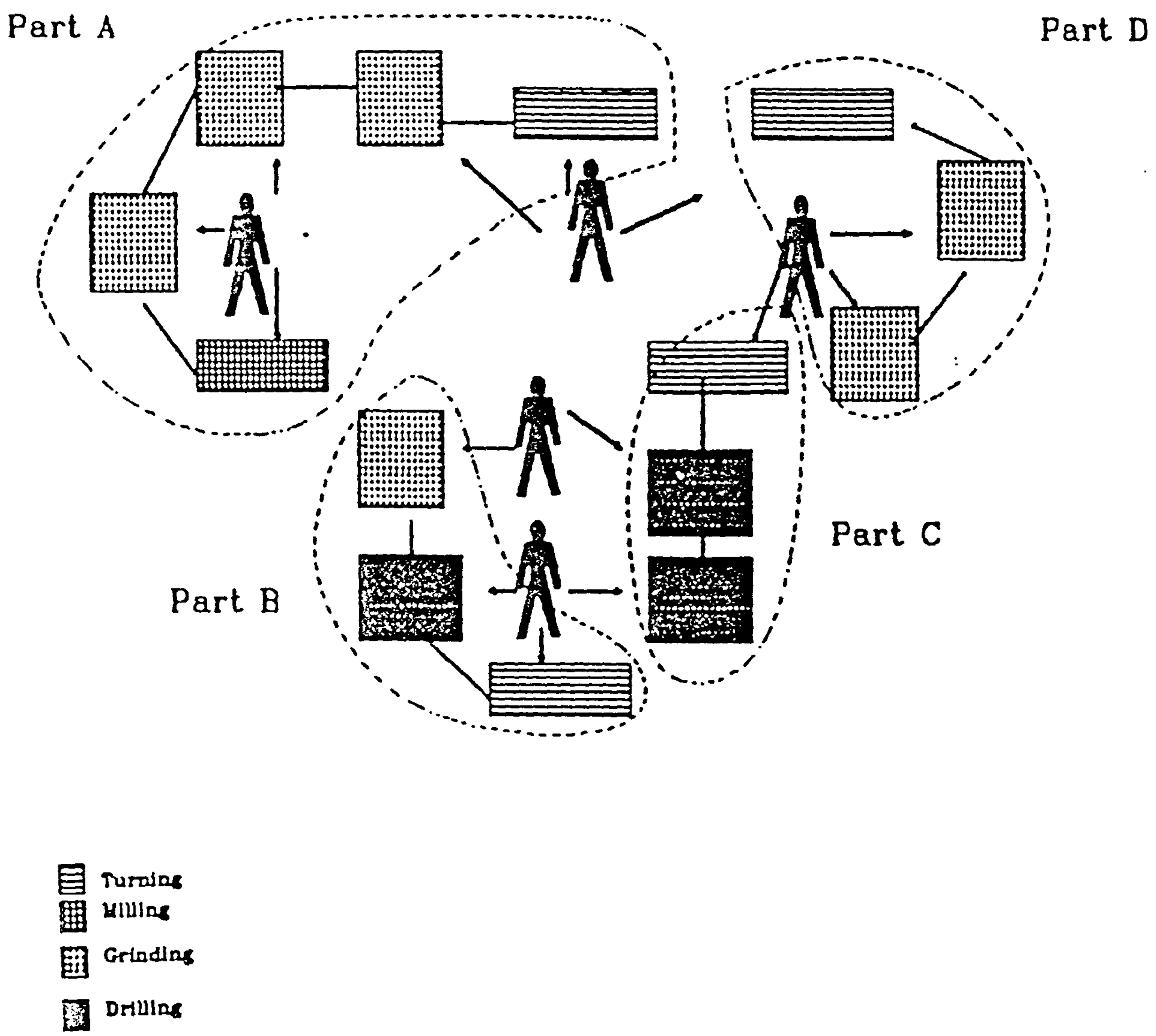

Figure 8.5 Movement of parts (A,B,C,D) through a J.I.T. cell

the cells are initiated and then integrated. This can be shown by the following example.

The demand for parts from cell X has increased slightly. To meet this extra demand, another operator has to be assigned to the cell. However, he will not be fully utilized by cell X (to fully utilize his services, the production of the cell would need to be increased! Definitely not allowed!). The demand for parts from the adjacent cell Y also increases slightly, justifying another worker. Instead of assigning another worker to this cell, the worker that is partially utilized in cell X could also work in cell Y. In this way, workers are fully utilized but the production rate is maintained at the desired level. See Figure 8.5. Again, the need for the cells, and the machines within the cells, to be situated in close proximity to each other is shown.

Many manufacturers will immediately criticize the cell layout because the machines will, for the most part, not run at full capacity. But, the cell should only produce at the rate that the parts are needed in final assembly. Any excess production will result in unwanted, costly inventories. The key is to produce at the rate of demand not at the maximum capacity of the machine.

With this new method of production comes a need for a new cost accounting method. Typically the product standard cost decreases as the lot size increases by reducing the effect of the set up and overhead costs per part. Now, as the lot size is reduced the cost per part appears to increase dramatically. This is, however, not the case. The conventional system is not designed to take into account the new savings in reduced labor cost and material handling costs. There will be varying standards for production time per piece because the demand for the part varies. So, a new system for calculating the product standard cost must be developed.

8.4 Savings Due to the Implementation of Just In Time.

The cost benefits of this philosophy are varied and can be significant in many areas. Obviously the savings due to reduction in set up times become immediately evident, Fisher Control reported a reduction in set up time of 30 to 35 percent. Lot size reduction allows the amount of inventory to be reduced dramatically. There are not only reductions in work in process inventory, but also in raw material and finished goods inventory. As workers are more efficiently utilized, the overall levels of manpower can be reduced. The reduction of lot sizes also drastically cut the throughput lead time of parts resulting in a decrease in the backlog of orders [19]. In many cases, the machines are run under capacity, thus repair work is reduced. This is also a factor of a preventive maintenance program in which operators are encouraged to take care of the machinery. Quality also increases due to the small lot sizes, so the costs due to scrap is reduced significantly. The cell layout and set up reduction philosophies stress the use of small volume, less technical machinery which is considerably cheaper than the high tech, high volume machinery used to produce large lot sizes in the job shop environment. The amount of space needed for storage is reduced - allowing these areas of the plant to be put to better use. There is also a reduction in the equipment needed for material handling.

The previous cases are areas where the improvement in the process has resulted in a measurable cost benefit. There are many cases where it is difficult to put a monetary value on the improvement. As the number of process plans become reduced and standardized, it is usually found that many of the standard times are in error. Although the task of re-evaluating these times appears daunting, it does eventually prove worthwhile and cost efficient. Any attempt to measure the cost benefit of this task would be very difficult though. More challenging job specifications for each employee result in happier, more satisfied people and better communications between the employees and management. Improvements are also obtained in customer relations as quality and lead times are improved and these improvements passed on to the customer. Savings are made in the area of obsolescence, there are now no large inventories sitting on shelves that can become outdated. With the cell layout, there is a reduction in the amount of traffic travelling through the plant which will reduce the dangers of losing parts or damaging them. The group technology coding and Kanban systems will reduce the amount of paperwork released to the floor which will without doubt remove some of the confusion on the floor.

Savings can be made in many areas of the manufacturing operation, not all of them will be measurable in monetary terms and neither will they all be immediately visible. They are eventually all available to the manufacturer. Time must be taken to ensure that these benefits are gained to their maximum advantage.

9. CONCLUSION AND DISCUSSION

Today, our major industries have to be competitive not only in the U. S. but in a worldwide market. Their superiority in terms of design and manufacturing ability has been challenged and successfully beaten, in many cases by the Japanese industries. In order to succeed, U. S. industries have to compete with the world on the basis of their manufacturing technology as well as their design technology.

The major competitive theme for the eighties and nineties is Customer Satisfaction in terms of competitive features, capabilities, quality, reliability, serviceability, price and delivery.

Typically, the traditional manufacturing process has included large inventory buffers to cover problems with quality, machine breakdown, inadequate scheduling, over complex process design and delays in delivery of purchased parts and raw materials. However, these high inventory buffers have served only to increase the final cost of the product. In no way does the value of a product increase when there are large amounts of inventory sitting around the shop floor! In fact, as well as the cost of the inventory, it also creates the attitude that defective parts and an inefficiently developed production process are allowable because there is always going to be extra material available to complete the order.

The ideal manufacturing process would have a flow that used only quality material in a quality manufacturing process. Inventory would be minimized because there would theoretically be no scrap. Just In Time is Manufacturing, however, is considerably more than an inventory control system. There are seven areas of focus of Just In Time manufacturing:

- Management Philosophy
- Factory Planning
- Quality Management
- Product Design
- Process Design
- Flexible Manufacturing
- Vendor Resource Management (Just In Time delivery of supplies by the vendors)

To achieve Just In Time manufacturing, all functions of the company must be involved such as manufacturing, industrial engineering, manufacturing engineering, production control, equipment maintenance, distribution, information systems, purchasing, product development and quality. Just In Time is an ongoing examination and improvement effort which will ultimately require the integration of all of the above functions. The integration of these functions will produce a system which can achieve:

- an optimally balanced flow (demand pull) with no waste

- and yields the lowest possible cost, defect free product on time.

In short, all elements that do not contribute to value added are waste and should be eliminated.

Without a doubt, the only way to achieve this is to obtain the commitment of the work force and management staff to the program. The secret to the success of Just In Time is the mindset of all those involved in the program. This factor appears to be relatively simple to implement, however, the attitudes and beliefs of human beings are often the most difficult to alter. The task become even more difficult if the people have been used to operating in one way for many years.

The education of employees can be carried out in many different ways, there are several requisite schemes that should be initiated:

- Formal training of Just In Time fundamental techniques
- Formal training of Total Quality Control concepts and techniques.
- Continual training in the above concepts as new

innovations and methods are realized.

- Similar training programs for all levels of staff including senior management and administrative staff.
- The accomplishments that have been achieved and are possible at the plant.
- The potential benefits of operating under this system to the employee, such as incentive schemes and suggestion programs for improving quality, lowering cost or eliminating waste.
- Emphasis on the increased amount of trust, respect and responsibility that is to be placed on the employees. This includes the implementation of Jidoka, the system that gives the worker the power to stop the production process when he spots a defect or some other problem. This in effect, requires every employee to be a quality inspector as well as a machine operator.
- Try to open as many communication channels between management and the work force. Implement quality circles formed with employees at all levels to work on various problems in the plant. Encourage social activities for ALL personal to be invited. Publish a news sheet informing all employees of the current status and accomplishments reached.

This education and awareness program must be implemented before any major alterations in the production process of the plant. It also needs to be set up for everyone in the plant, not just those personnel who are going to be involved in the immediate plan. Once this phase has begun, the conversion of the plant to Just In Time operation can begin.

The objective here, is to redesign the flow process. How one goes about this will depend on the experience and philosophies of the manager in charge of the implementation program. Concepts that need to be examined include:

- group technology
- cell layout
- reduction of set up times/ changeover times
- implement total quality control program
- reduction of lot sizes
- balance the work station capacities
- emphasize preventive maintenance
- try to overlap operations
- stabilize the schedule
- underutilize capacity
- standardize the production process as much as possible
- STRESS THAT ALL OF THE ABOVE FACTORS DEMAND CONTINUAL ATTENTION AND CONTINUAL IMPROVEMENT !!!

These factors should be applied to a small area or 'island' of the plant on a trial basis. The employees in the particular area should be encouraged to contribute suggestions and improvements as much as possible.

While set up reduction, cell layout, group technology and a comprehensive quality control program are vital to the success of the implementation program, the other factors cannot be ignored. Attention should be paid to all of the factors listed above and time and work put in to improving all aspects of the production process in that part of the plant.

Just In Time manufacturing is extremely sensitized to the smooth flow of material through the plant. If there is even one small hitch in the flow due to defective parts, machine breakdown, etc., then the flow and production capability of the whole plant is affected. The vital factor in terms of Just In Time manufacturing from the point of view of implementing techniques is the ability to synchronize and coordinate the factors so that they all contribute to the smooth flow of the process with maximum benefits.

Once this so-called island of Just In Time has proved to operate successfully, the next area should be selected for implementation. This process of creating various islands of Just In Time should be continued until as much of the production process has been converted as is feasible.

Once the plant has been converted into 'islands', the next stage is to mesh the islands into one complete Just In

Time operation and synchronize the flow throughout the plant.

The final area of change and adjustment to Just In Time manufacturing is the modification of the information reporting systems. The systems need to be altered to allow for the changes in inventory recording, the formulation of the product costs and the demand pull system.

9.1 Final Observations

The proposed strategy provides only a direction for implementing Just In Time manufacturing. It has become clear through the examination of the case studies of manufacturers' attempts to implement Just In Time that each plan is very individualistic. The strategy in Chapter 8 assumes that each stage will be completed with 100 percent success and that there is total commitment from management and labor force alike. In the text book world this is possible, but in the real world there are likely to be many other factors that will reduce the effectiveness of Just In Time manufacturing.

An example of such a factor is the fact that there is likely to be some machinery in any plant for which it is very difficult to reduce the set up time on. If the set up time on the machine cannot be reduced then it is impossible to reduce the lot size on this particular machine. Any attempt to reduce the lot size on a machine which has not had any set up time reduction will adversely affect the flow of the material. Thus in the implementation of Just In Time, care must be taken in deciding which areas of the plant will be receptive to Just In Time manufacturing and which will not.

Process plants such as those in the Plastics industry have found only a limited use for Just In Time manufacturing. These plants produce large batches using very capital-intensive facilities. Thus the basic concept of reducing lot sizes is often not practical.

Certain aspects of Just In Time are rarely implemented. The best case of this is the Demand Pull/Kanban system [29]. The majority of plants have some sort of Material Requirements Planning computer program already installed, which creates schedules for purchased materials, contributed parts and final assembly. Some plants are using Kanban to control the queues between several of their operations but few have connected the majority of their operations with pull signals.

Finally Just In Time is taking considerably longer to implement than was expected [30]. Toyota Japan estimated that it took their suppliers between three to five years to convert to Just In Time. However, U. S. plants are taking considerably longer with many of them, so far, having only achieved a 50 percent implementation level. This is due in part to the size of some of the companies and their complexity. But mostly it is due to the problems in changing human behaviour.

For U. S. manufacturers to be able to compete effectively with the rest of the world, Just In Time manufacturing has to become a major contributor to their manufacturing process. Above all, implementers need to understand that Just In Time is an evolutionary process that continues over an unlimited period not an overnight revolution that happens only once.

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11. APPENDIX I SAMPLE COPY OF THE SURVEY

Iowa State University of Science and Technology Ames, Iowa 50011

Department of Industrial Engineering
212 Marston Hall
Telephone 515 294-1682

November 21, 1988

Dear Sir/Madam,

I am currently studying for my Master's degree in the Industrial Engineering Department at Iowa State University. My research is in the area of Just-In-Time manufacturing, more specifically the evaluation of the critical manufacturing techniques necessary for the successful implementation of Just-In-Time.

As part of this research, I am sending out this questionnaire to any company with experience in Just In Time manufacturing.

I would be extremely grateful if you could spare the time to answer the questions and or provide any documentation of your plant's experience with JIT, particularly with respect to the manufacturing techniques used prior to and post JIT implementation.

From the literature that I have read, your company seems to have had major exposure to JIT and so I feel that any information you could offer would be extremely beneficial to my research.

Should you have any questions regarding the survey, please feel free to contact me at (515) 294-2467. My major Professor, Victor M. Tamashunas will also be available for questions at (515) 294-7733.

I would be grateful if you could return this questionnaire as soon as possible.

Sincerely,

Sarah F Davies

Sarah F. Davies
Graduate Student
515 294-2467

SFD:jh

NOTE:

Please forward this survey to relevant personnel.

1) Describe the production system (circle any appropriate).

Repetitive
Low volume
High Automation
Continous flow
High volume
Job Shop
Low automation

Other:

2) Briefly describe the types of products made at your plant.

3) Please indicate which, if any, of the following techniques/ policies were used in the manufacturing system, prior to Just-In-Time implementation.

Please describe how these techniques/policies were implemented in your operation.

Lot size determination
Plant layout e.g. cellular, assembly line etc.
MRP
Scheduling of jobs
Sequencing of operations
Material Handling systems
Aggregate Production Plan
Storage facilities
ABC classification/inventory policy
Group Technology

Other:

4) After the Just-In-Time implementation, how were these techniques/policies affected.

5)When was Just-In-Time implemention begun?

6)Why were J.I.T. methodologies introduced?

7)Describe the implementation program, specifically with respect to the manufacturing techniques used and or modified.

Discuss the pilot projects used in the implementation.

8)From your experience of implementing Just-In-Time in your plant, please rate the following manufacturing techniques with respect to their importance in the succesful implementation of JIT.

Cell layout
Set-up reduction
Lot size reduction
Production at point of use
Kanban style sequencing and scheduling
Quality control
Mixed model production
Cross-trained employees
Housekeeping
Stable production levels
Other factors:

For the four most important factors, explain why they were so critical to JIT success.

9) How important is employee involvement to the success of JIT? Please describe your Employee Involvement program.

10) Please note any other comments on the criteria needed for successful JIT implementation, in particular from a manufacturing techniques standpoint.

12. APPENDIX II SAMPLE COPY OF THE CONDENSED SURVEY

207 Apple
Ames, Iowa
50010

March 28th

Dear Sir,

Several months ago (November '88), I sent out a survey to your company requesting information about the Just-In-Time implementation program that you used in your manufacturing division.

As a result of the survey response, I would be extremely grateful if you could reply to this shortened version, so that some of the responses can be clarified.

I would appreciate it very much if you could spare the time to fill out the questionnaire as soon as possible, and return it to me no later than April 15th.

Thanking you in anticipation

Sincerely,

Sarah F. Davies
Graduate Student - Iowa State University,
Department of Industrial Engineering
212 Marston Hall
Iowa State University
Ames, Iowa
50010

Survey to determine possible strategies for Just-In-Time implementation.

1) Describe the production system (circle any appropriate)
   Repetitive   Low Volume   High automation
   Low automation   Continuous   Job shop

   Other :

2) What were the previous manufacturing techniques used.
   E.g. M.R.P., Aggregate production planning, ABC analysis, group technology, cell layout, conventional lot sizing, F.M.S., assembly lines process layout, product layout.

   Other :

3) How long has Just In Time manufacturing been in use at the plant, and what percentage of manufacturing process use Just In Time techniques ?

4) In your implementation of Just In Time, which manufacturing techniques were the most important in it's successful implementation. (Please list in order of importance.)

   Set Up Reduction
   Cell Layout
   Lot Size Reduction
   Kanban style sequencing and scheduling
   Mixed model production
   Quality control
   Cross trained employees
   Employee involvement
   Stable production levels
   Production at point of use