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THE APPLICATION OF JUST-IN-TIME
TECHNIQUES TO SMALL TO MEDIUM
SIZED MANUFACTURING COMPANIES

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in partial fulfilment of the requirements for the degree of
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ABSTRACT

Just-In-Time (JIT) Production evolved in Japan as a result of the need to increase both productivity and manufacturing flexibility. It was initially applied by the large, repetitive manufacturing companies, but was soon adopted by the smaller manufacturer. JIT has only relatively recently found its way into Western manufacturing industries.

JIT aims to only produce the products that a customer requires, and at a rate which will just satisfy demand. Organizations run under JIT should produce perfect quality products with minimum lead time. There should be little manufacturing waste, and the personal development of people should be encouraged.

There are a number of techniques which enable these requirements to be met. Workstation setup times must be reduced. The establishment of a preventive maintenance programme helps increase machine availability and process capability. Employees should be trained to operate as many machines as possible, thus increasing their flexibility. Mutually beneficial deals can be arranged with suppliers for the Just-In-Time delivery of purchased parts. And finally, a pull system should be installed. All of these measures aim at reducing waste and increasing plant flexibility and productivity.

Although the understanding of the principles behind JIT is simple, its application in practice is difficult. To compound the problem, certain aspects of JIT tend to be more difficult for the small than the large manufacturer to apply. Yet it is necessary to go this route if industrial productivity in this sector is to be improved.

In order to determine which aspects of JIT Production are the most difficult for the small manufacturer to apply, and in order to be able to set out general guidelines for the organization wanting to implement JIT Production, the redesign of a press shop in a small manufacturing plant was undertaken. From this a number of significant points emerged.

The first of these was the importance of planning and the establishment of JIT goals. Such a programme will be hindered by inadequate long-term planning, and so this function should be carried out thoroughly. It is important too, to make an adequate assessment of the existing production situation prior to converting to JIT. Failure to do this may mean that management will not have a clear view of how changes have affected their situation.

The selection of suitable implementation teams, and the training thereof is also vitally important. Even the most well-intentioned JIT programme will fall short of expectations if people do not accept these new ideas.

The revision of physical aspects of production eg. plant layout, is necessary if all forms of manufacturing waste are to be reduced or eliminated. Attention should be paid to each aspect, and problems eliminated prior to the installation of the pull system. Otherwise, complications will result.

The heart of JIT is the elimination of all forms of manufacturing waste. This is true both of the large and small manufacturer. Basic common sense will enable this to be achieved and the goal of stockless production will come closer.

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CHAPTER ONE
INTRODUCTION

The adoption of Just-In-Time (JIT) Production techniques by manufacturing companies has enabled producers to become extremely flexible. This flexibility has meant that they can now produce exactly what is needed by a customer and no more, and that the goods can be delivered precisely when required. It is in being able to do this that any one manufacturer will have significant competitive advantages. Productivity, as well as quality, can be increased substantially in companies run under JIT, and it is because of this that these new manufacturing techniques have drawn interest.

JIT evolved in Japan; the result of much concerted effort by the large, repetitive manufacturing organizations. The small manufacturer soon followed suit in the application of these new ideas. In the West, as in Japan, JIT was first applied to the large manufacturer. This was the case here in South Africa, with such companies as General Electric and Toyota being among the first to install JIT systems. The small producer is now beginning to recognize JIT's potential.

Although the ideas and concepts behind JIT are simple enough to understand, their application in practice tends to be difficult. To compound the problem for the small manufacturer, a number of accepted JIT techniques seem not to be readily adaptable to his environment. The distinction between those techniques which are and which are not is not made clear. Many a company has thus had to learn them the hard way by means of trial and error. Even so, JIT is a necessary route to take if industrial productivity in the small manufacturing sector is to be improved.

This thesis aims at filling this knowledge gap, by attempting to distinguish between those aspects of JIT which can and cannot be readily applied by the small manufacturer. In order to draw the necessary conclusions, the research was broken down into four main sections. These were:

1. To study in as much depth as possible the concepts which underlie the philosophy of JIT Production, and to set them out in a logical manner. The emphasis in this first section was to introduce the person with no prior knowledge of JIT to the basics. A survey of the type of manufacturing environment to which JIT has been applied, along with its degree of success, was to be included.
2. To set down general guidelines as to how to introduce JIT Production. These guidelines were to be as broad as possible in order to cover the whole scope of JIT, and not be aimed at any one type of manufacturer, big or small.
3. After having selected a suitable small manufacturer, to attempt to redesign all or a part of his production system along the lines called for by JIT thinking. If possible, the design was to be put into practice.
4. From experience gained, to try to identify those aspects of JIT Production which are most readily applied to the small manufacturer and from which the most benefit may be obtained. Also to identify those techniques not so easily applied, and to highlight potential implementation problems.

The investigation was based on the design and evaluation of a revised production system in a press shop in a small manufacturing company; a company which supplied components to the motor industry. The press shop was chosen for this redesign as it was proving to be a big bottleneck area. The contents of the report are outlined below.

CHAPTER TWO comprises a literature survey. This survey briefly outlines the history of the development of JIT, and examines some available material on the various JIT techniques. JIT's introduction in a number of organizations is described. The difficulties of applying JIT to both the small and large manufacturer are discussed.

CHAPTER THREE describes the main concepts behind JIT Production. The five requirements of a JIT system are stated, and are elaborated in terms of eight separate elements. The application and purpose of the Kanban is discussed. The chapter aims at providing as broad an introduction as possible to the topic.

CHAPTER FOUR sets out general guidelines for the introduction of JIT into a manufacturing plant. These guidelines are drawn from available literature and make no distinction between those aspects which are easy, and those which are difficult, for the small manufacturer to apply.

CHAPTER FIVE examines and defines the production problems existing in the press shop of a small manufacturing plant prior to the implementation of JIT.

CHAPTER SIX describes the implementation of the press shop JIT pilot project in the small manufacturing plant. It discusses training necessary prior to JIT implementation, and describes the redesign of the production facility taking into account floor layout, materials handling and tool storage. The establishment of a setup time reduction programme and a preventive maintenance programme are outlined.

CHAPTER SEVEN summarises the difficulties encountered in implementing the JIT programme in the small manufacturing company. It summarises problems with regard to training, planning, the physical revision to plant layout and equipment, the establishment of a preventive maintenance programme and the reduction of setup times.

CHAPTER EIGHT concludes with a list of recommendations to be made to the small manufacturer wishing to embark on a JIT programme.

CHAPTER TWO

LITERATURE SURVEY

2.1 INITIAL APPLICATIONS OF JIT

JIT Production has been most successfully employed in Japan in large, repetitive manufacturing environments. The motor industry is a prime example, and Toyota's Total Production System, of which JIT is but a part, has been much studied and publicized. The implementation of JIT by North American manufacturing concerns was also begun initially by large, repetitive manufacturers, and such pioneering companies include the likes of General Electric, Hewlett Packard and General Motors. Many other industries are currently involved in JIT efforts, including those of weaving, tyres, paper and packaging, semi-conductors and plastics.

The benefits of applying JIT not only to repetitive manufacturing but also to job shop environments were soon realized, but here again it was the large manufacturer who pioneered this area. Spurgeon describes the implementation of JIT programmes in both job shop and flow shop plants. These plants are both owned by General Electric, and are situated in the United States. The improvements and productivity increases obtained are outlined for both cases, and a comparison of the two approaches to JIT implementation is given.

As in the United States, South African industries have only recently realized potential JIT benefits, and programmes were initially launched by a number of the larger manufacturing companies. This was soon followed by several smaller repetitive and batch manufacturing industries. Even so, according to Finch there has been little research into applicable production planning and control techniques for such environments.

2.2 SETTING UP FOR JIT - SOME APPROACHES

A number of key personnel involved in JIT programmes, both in South Africa and the rest of the world, have published papers

detailing their approaches to setting up for JIT Production.

Carstens (1985) describes the introduction of JIT by an electric motor manufacturer in South Africa. He outlines how their product range was divided into a number of sub-ranges, which could each be handled separately. The company then drew up a list of the technical requirements for successful JIT implementation. The designed system was introduced initially on one product range only, and this was used by all concerned as an opportunity to learn about implementation problems. Carstens stated that the key to a successful JIT programme was the reduction of setup times, and describes some specific techniques enabling this.

Carstens and Stroebel (1985) outline how JIT may be introduced into a foundry, and conclude by stating the benefits to be derived from the successful adoption of JIT by South African manufacturing industries.

Schwind (1985) discusses the approach adopted by Harley-Davidson in the United States in establishing JIT Production. The reduction of setup times was also cited as their prime requirement for a successfully implemented programme. Three phases in reducing setup times are described. Communication within the company was recognized to be of vital importance right from the outset.

Andrew puts forward a general guidance as to how to implement these new JIT ideas into Western manufacturing firms.

Although the major JIT efforts have been limited to the large manufacturer, the small manufacturer may also benefit from JIT. Krepchin (1986) describes the implementation of a JIT programme at Linden Products, a small parts supplier to the automotive industry. Linden's approach was to begin with an education programme aimed at letting all concerned know exactly what JIT is and what it can achieve. The identification of the major problem areas in the plant was the next step, followed by setting out goals to be achieved. Reduction of setup times and attention to the flow of work in a process were the two aspects

of production which were considered to be the biggest trouble areas. Attention to these problems achieved the added benefits of reduced lot sizes and work in progress, as well as of improved quality. Working with suppliers, to deliver the required quantities of material at the right time, was also carried out as a part of Linden's overall programme.

2.3 JIT AND THE SMALL MANUFACTURER

Some of the elements of a JIT Production system, which may be perfectly suitable for application by a large firm, are more difficult for a small one to introduce.

Finch and Cox (1986) break down the eight elements of JIT Production into two groups; those which are independent of a firm's size, and those which relate to the size and consequently may be more difficult for a small manufacturer to satisfy. The implication made by Nelleman and Smith (1982), that the implementation of any one part of JIT without the rest would be a failure, is incorrect. If this were so, then any attempt made by the small manufacturer to implement JIT should in theory be abandoned. Says Finch, "A realistic approach for the small manufacturer may be to strive to attain these requirements one at a time, simply for the benefits of that particular requirement, and not to move toward a total JIT system." He concludes, "An all or nothing approach to JIT is not the best plan of attack for the small manufacturer. The individual components provide benefits and should not be dismissed because a total JIT system is not feasible."

Krepchin (1986) suggests that smaller plants may even have an advantage over larger ones when it comes to implementing JIT. The reason for this, he says, is that "there is less inertia to overcome, and often more willingness to try new approaches. And results are seen faster - positive reinforcement for further efforts."

2.4 SOME DIFFICULTIES OF SETTING UP FOR JIT

Although the benefits that may be obtained by a company adopting JIT Production are enormous, there may be practical difficulties in establishing the new system. Wheeler suggests that a company which has decided on JIT should answer a number of questions. Although they might at first seem superficial, they give a quick but accurate indication of the status of the company and its readiness for JIT. He suggests that operating data be collected in order that a "total opportunities figure be developed". This data should include inventory levels by commodity, lead times and machine downtimes. Without sufficient and adequate data, JIT programmes are difficult to implement successfully.

Other factors which were found to hinder the success of JIT, as was discovered by General Electric (SA), were a lack of preventive maintenance, limited worker flexibility, a high accumulation of work in progress, and a resistance by factory personnel to change. And in the case of working in co-operation with suppliers, Kenfield (1986) recommends that manufacturers have their in-house JIT processes operating effectively before passing the challenge on to the suppliers.

Goddard (1984) recognizes the need for an effective shop floor control system for a JIT environment. Without this system, which he maintains should be computer-based, it may be that a company makes enough product in total, but may not be working on the right jobs. Conversely, it may be working on the right jobs, but not be producing enough in total.

CHAPTER THREE
JUST-IN-TIME PRODUCTION : AN EXAMINATION
OF THE UNDERLYING CONCEPTS

It is important from the outset to know precisely what is implied by Just-In-Time (JIT) Production. JIT has recently become a buzzword in Western manufacturing. One reason for this has been the realization that by adopting the various JIT techniques, significant productivity increases may be attained. An added incentive to converting a plant to JIT Production is that these productivity improvements may often be had for a relatively low capital investment. Having realized this, many manufacturers have started out along the road towards either a total or "partial" JIT Production system.

JIT emphasizes the production of exactly what is needed, and its conveyance to exactly where needed, precisely when required. The overall goal of stockless production, as JIT is sometimes called, is, according to Hall (1983), "To find practical ways to create the effect of an automated industry which will come as close as possible to this concept of ideal production."

The above idealized goal is impossible to attain. Even so, the current production system of a manufacturer wishing to introduce JIT will have to be changed in order to proceed towards this stated goal. Such a revised production system should fulfill a number of requirements:

- It should produce products the customer wants at a rate which will only just satisfy demand.
- It should produce with perfect quality.
- It should produce with zero lead time.
- It should produce with no waste, either of labour, materials or equipment.
- It should produce by methods which allow for the development of people.

Eight elements behind a successful JIT system are identified, elements which enable the manufacturer to attempt to satisfy the abovementioned requirements. These elements are listed by Finch and Cox (1986) as:

1. A focussed factory.
2. Reduced setup times.
3. Group technology.
4. Total preventive maintenance.
5. Cross-trained employees.
6. Uniform work loads.
7. Just-In-Time delivery of purchased parts.
8. Kanban.

The five requirements of a successfully implemented JIT programme are discussed more fully below, and are elaborated in terms of these eight JIT elements. It should be realized that although the concepts behind JIT are simple to understand, to present them in a logical order is difficult, as every aspect of JIT Production interacts with every other.

The focussed factory concept, mentioned as Element One above, requires that a particular production system be specifically designed for a limited number of product lines. This eliminates potential conflict between the differing production needs of the various products. A factory design along these lines may prove to be very limiting, and is not elaborated.

3.1 PRODUCING JUST TO SATISFY CUSTOMER DEMAND

A factory's ability to produce whatever the customer demands, and at a rate which will only just satisfy this demand, requires extreme manufacturing flexibility. This flexibility means that plant equipment must be able to change from one operation to the next almost immediately.

There are a number of factors which limit flexibility. One of these is the large proportion of available production time usually required by most manufacturing concerns to setup

machines for a new production run. Plant housekeeping too, plays an important rôle in developing a flexible manufacturing plant. These, however, are not the only two factors which lead to flexibility. The various systems within an organization have to be capable of supporting production. For example, little benefit is obtained by having very small setup times while at the same time utilizing a material handling system incapable of delivering the necessary parts to a work centre on time.

3.1.1 PLANT FLEXIBILITY AND REDUCED SETUP TIMES

Much time has traditionally been spent on setup operations. One of the major reasons for this has been the lack of awareness of the effect of setup times on overall manufacturing flexibility.

One of the first to realize this fact was Shigeo Shingo (1985) who, over a period of some twenty years, developed what he called the Single Minute Exchange of Dies (SMED) system. His SMED system has been applied to a large number of manufacturing organizations, and remarkable decreases in machine setup times have been achieved; setup time reductions in the order of 90-98% of previous times for some operations.

The basis behind his success in achieving these reductions is that he recognized that any machine setup can be separated into two separate operations; internal and external setup. Internal setups involve those operations which can only be performed while the machine is stopped, such as the unbolting of an old die. External setups are defined as those operations which can be performed to prepare for the next setup while still on the present production run. Such operations may include the fetching of the next press die, or any tool setting which can be performed off a machine. The more external setup the better, and machine downtimes due to this cause will be proportionately reduced. APPENDIX A describes the SMED concept in greater detail.

There are many other factors, beside reduced setup times, which lead to plant flexibility and enable a manufacturer to produce solely to customer requirements.

3.1.2 PLANT FLEXIBILITY AND HOUSEKEEPING

Plant housekeeping is an important factor leading to a flexible manufacturing plant. The saying "a place for everything, and everything in its place" is particularly applicable if tools and equipment, stock and work in progress are to be found quickly. Reduced clutter arising from good housekeeping not only helps material to flow faster through the factory, but also aids in decreasing machine setup times.

Increased plant flexibility is a vital pre-requisite to producing products the customer demands at a rate which will only just satisfy demand. Without flexibility, this requirement of a successful JIT system is difficult to fulfill. APPENDIX B outlines the advantages of small lot sizes, which are only made possible by increased plant flexibility. This is opposed to the large lot sizes which are called for by conventional production thinking.

3.2 PRODUCTION WITH PERFECT QUALITY

This second requirement of a JIT system is necessary for there to be a fast flow of parts through production in small lot sizes.

A philosophy of perfect quality production means that there should be no rework of components, there should be no over-production to allow for scrap which would normally arise, there should never be a need to scrap material resulting from production adjustments, and there should be no damage arising from the transit of work in progress material. In other words, the product should be made properly the first time.

In order to produce with reduced or zero defects, there are two major concepts that have to be accepted and applied. The first is that everything possible must be done to prevent defects from occurring in the first place, and the second is that if defects do occur, they must be detected as quickly as possible and immediate corrections carried out. If these two concepts are

correctly applied, defect levels should at worst remain the same, but in reality should decrease.

3.2.1 PREVENTION OF DEFECTS

Defects occur originally for three major reasons:

1. Workers lack sufficient knowledge or skill.
2. Management has failed to establish consistent quality standards.
3. Workers make mistakes due to carelessness, boredom and distraction.

Mistake proofing, or Poka-Yoke [14], is one way of eliminating careless mistakes. An example includes the use of fixtures to eliminate misassembly. This method is very positive as an operation cannot take place if an error is made. The sounding of alarms or the use of a precautionary check list is another way of eliminating or reducing mistakes.

Manufacturing errors can also arise from machine failure. The goal here is to eliminate errors from this source before they occur. In order to achieve this, a little time each day should be scheduled for the checking and maintenance of equipment. Added benefits to scheduling maintenance time is that equipment should be in a position to produce whatever is needed when it is needed, and that the slack time provided for machines enables them to catch up production in the case of tightly balanced material flow. A total preventive maintenance programme is usually argued against as it is assumed to cost more than repairing machinery as and when it fails. However, by establishing such a programme, equipment availability is improved, and its performance is likely to be enhanced over time.

3.2.2 DEFECT DETECTION AND CORRECTION

Toyota and Hitachi's philosophy with regard to error detection is to have each worker perform a 100% inspection. Needless to say, this is not always possible, but nevertheless control should be given to the worker enabling him to either make

immediate corrections or summon help quickly when something goes wrong.

This is a different approach to the way defects are normally corrected in most plants, where inspectors are responsible for finding the defects, and someone from quality control initiates corrective action. This of course will vary from company to company, but generally it holds true. This new approach to quality control will thus require a different mind-set.

Along with this revised approach to quality, a system needs to develop enabling fast feedback and which allows for the rapid correction of errors. Process controls should be established and a process and product surveillance plan should be implemented to recognize when conditions go out of control. The surveillance plan should include such aspects as monitoring the input material and the process parameters themselves. The plan is aimed at confirming that the process is in control, or enabling abnormalities to be corrected quickly when they are discovered.

The whole concept of striving for zero defects is an ongoing one, with defect levels in the order of Parts Per Million achievable. Whatever a particular company's approach to achieving perfect quality, the success of a programme can be judged by the change in defect levels. FIGURE 3.1 describes a Parts Per Million control system as applied in a JIT environment.

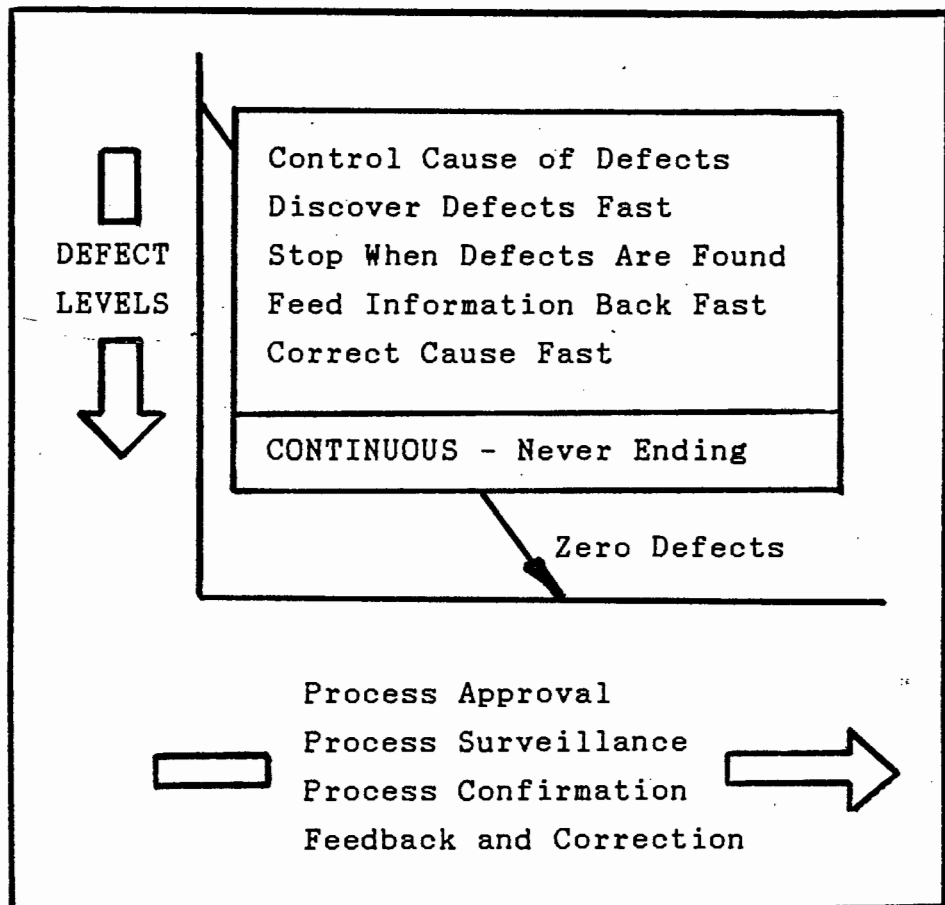


FIGURE 3.1 : A Parts Per Million Control System

3.3 PRODUCTION WITH ZERO LEAD TIME

The production of components in small batches, made possible with a flexible manufacturing plant producing with perfect quality, is a stepping stone to (ideally) zero lead time production.

Traditional manufacturing techniques have been characterized by long lead times and high levels of Work In Progress (WIP), both of which lead to increased production costs. However, small batches which are produced perfectly (ie. there is no need for rework) are able to move through a plant more quickly. Consequently, production costs are decreased and WIP inventories are reduced. There are many other added benefits.

These are not the only two factors of production enabling zero lead times. The reduction or elimination of any form of manufacturing waste is also necessary. SECTION 3.4 describes these various forms of waste and their elimination.

3.4 PRODUCTION WITHOUT WASTE

The elimination of waste is one of the prime objectives of a JIT production system. Waste comes in a variety of guises, and not only refers to wastage of material. Toyota's term for waste is muda, and they subdivide this muda into seven categories:

1. Waste of Over-Production.
2. Waste of Correction.
3. Waste in Processing.
4. Waste in Conveyance.
5. Waste of Inventory.
6. Waste of Motion.
7. Waste of Waiting.

3.4.1 WASTE OF OVER-PRODUCTION

This aspect of waste refers to the waste of producing components or finished articles in larger quantities than is actually necessary. In producing these large lots, time, which could have been spent on the production of needed components, is wasted on producing excesses, which then have to be stored. This is known as the waste of inventory.

To eliminate the waste of over-production, it has to be possible to produce in small lot sizes in manufacturing plants with a high degree of flexibility. This will enable customer requirements to be just satisfied and nothing more.

3.4.2 WASTE OF CORRECTION

The production of components or finished goods, which then have to be reworked, is a form of waste. Production with perfect quality is the way of eliminating this waste.

3.4.3 WASTE IN PROCESSING

Operations which add no direct value to a product, or which do not advance the production process in any way, are waste, and should be eliminated as far as possible. Such operations may include drilling an unnecessary countersink, or producing a better surface finish than required. By carefully considering the various processing operations that a part must go through in order to be made, waste from this source may be reduced or eliminated.

3.4.4 WASTE IN CONVEYANCE

Waste from this source arises from transporting components, raw materials and inventory. Such actions do not add any value to a product. Obviously it is necessary to move parts from one workstation to the next, and this is waste that cannot be avoided. However, such waste should be kept to a bare minimum. Workstation layout is an important factor in eliminating this waste, and the application of group technology is one of the tools for achieving this.

FIGURE 3.2 shows schematically the difference between functionally based work centres and group technology workstations. It can be seen that by classifying the various parts that are manufactured into families and setting out groups of dissimilar machines to construct the parts according to its family, it is possible to eliminate large amounts of conveyancing. This, however, requires the careful balancing of a layout to attain smooth flows.

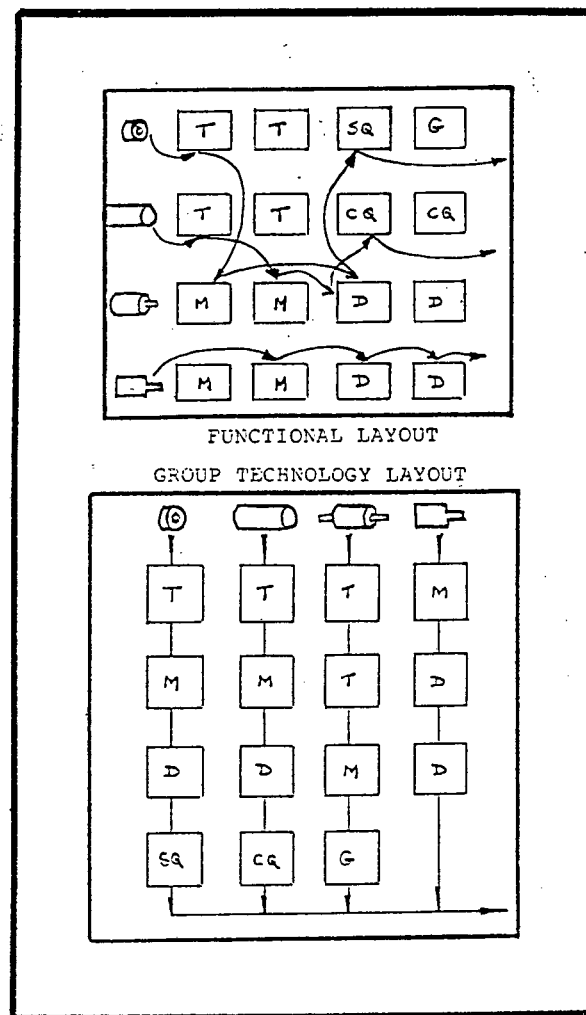


FIGURE 3.2 : Function vs Group Technology Layout

3.4.5 WASTE OF INVENTORY

Excess inventory resulting from over-production is wasteful. Space needs to be found to house this excess production or WIP inventory, and as well as tying up valuable space, large amounts of capital are employed in maintaining this stock. APPENDIX C describes this concept more fully.

3.4.6 WASTE OF MOTION

Any movement of people or equipment which is unnecessary in the production process does not add value to the product and should be eliminated. Good housekeeping is important here in being able to find equipment as needed, thus decreasing time lost due to unnecessary searching. Machine layout also plays a rôle in reducing this waste.

3.4.7 WASTE OF WAITING

Time spent waiting is wasted and such a situation should be corrected. Sometimes this is unavoidable, as in the case of an operator waiting for his machine to finish processing. By being constantly aware of waste in this area there may arise new ideas resulting in increased efficiency. Waste also arises from waiting for purchased parts to be delivered, and so by arranging mutually beneficial deals with suppliers for Just-In-Time parts delivery, such waste may be reduced or eliminated.

The seven categories of waste defined by Toyota are obvious once pointed out, but tend to be less so the longer an organization has been producing in its old "tried-and-trusted" manner. A constant awareness by both management and the shop floor worker of these forms of manufacturing waste will concentrate production and engineering efforts only on what is important, and help eliminate the unnecessary.

3.5 PRODUCTION AND THE DEVELOPMENT OF PEOPLE

The driving force behind any project, including that of the implementation of JIT, is people. From fully automatic manufacturing plants to small, entirely manual manufacturing concerns, people are involved. An organization can only be successful if its employees strive to work together as a team, towards a common goal.

This teamwork is especially required when implementing JIT, where people will be required to change their current ideas about what is "right" for their environment, and adopt new ideas and new approaches to production. The development of a team spirit takes experience and long-term development, and is one of the major challenges facing stockless production. However, changing ways of thinking cannot be accomplished overnight.

People must initially be told how to apply these often radically new ideas, and continually be encouraged to try to improve on them. A large amount of on-the-job development must occur; development which results from putting into practice new methods, and overcoming physical problems together.

Such on-the-job experience, along with encouragement, plays a large rôle in leading people towards the new attitudes and ways of thinking concerning stockless production. Hard and fast rules cannot be set down. It is up to each company to find a system which suits it best.

JIT is sometimes described not as a new method of manufacturing, but as a philosophy. This term concisely summarizes this whole area of developing people for JIT, and is a process which is ongoing and never complete.

3.6 KANBAN AND JIT

The pull system of manufacturing, and its use of Kanbans or pull signals, is but a small part of JIT Production, although it is often interpreted as JIT itself. A pull system emphasizes

the production of a part, or container of parts, at a workstation, but only when given the signal to do so by the following work centre, ie.as it is required.

A variety of Kanban systems has evolved, which can generally be divided into two groups; the dual and single card systems. Toyota developed the dual card system, which is only used by a few manufacturers. In this case, the Kanban cards used consist of a production Kanban, authorizing the production of one standard container of parts at the preceding work centre, and a withdrawal Kanban authorizing the movement of the container of parts to the next stock point.

The single card Kanban system is more commonly used, although its level of control at the preceding work centre is less. A standard container of parts plus Kanban moves to the succeeding work centre, and from here the Kanban is sent back to the first work centre where it authorizes the production of another standard container.

The use of cards is not the only way of controlling production. Kanban translates as "visible record" and may take the form of a painted square on a work table (as soon as the square is visible the preceding work centre knows to make a part, or container of parts, to place back on the square), or even just the container itself. Here an empty container authorizes the production of parts. There are many other forms of Kanban that can be used.

3.6.1 STIMULATING PROCESS IMPROVEMENT WITH THE KANBAN

Whatever the form of the Kanban, its true objective is to highlight production problems which may never otherwise be noticed, in order that they may be solved. Management by sight, a part of the Kanban system, is Toyota's term for the provision of visual control wherever possible. For example, the use of coloured cards, lights, hook boards, charts and graphs serves to identify problems as soon as possible. These signals must be made available to the workers so that they may be more generally aware of the production situation.

A pull system must be capable of controlling the inventory levels of any part at any point on the floor. The number of production cards (in a dual card system) should thus be set so as to allow only the number of parts required to be produced, and nothing more. Initially it may only be possible to produce numbers of parts which result in an inventory, but by continually tightening control as soon as production is running smoothly and withdrawing some cards from circulation, problems immediately become apparent and can be tackled. The eventual aim is to withdraw all Kanban cards to attain true stockless production. With this in mind management should never be satisfied with the status quo but should be continually striving for improvement.

A summary of the main concepts and elements already presented and which form the basis for a successful JIT programme is shown in FIGURE 3.3.

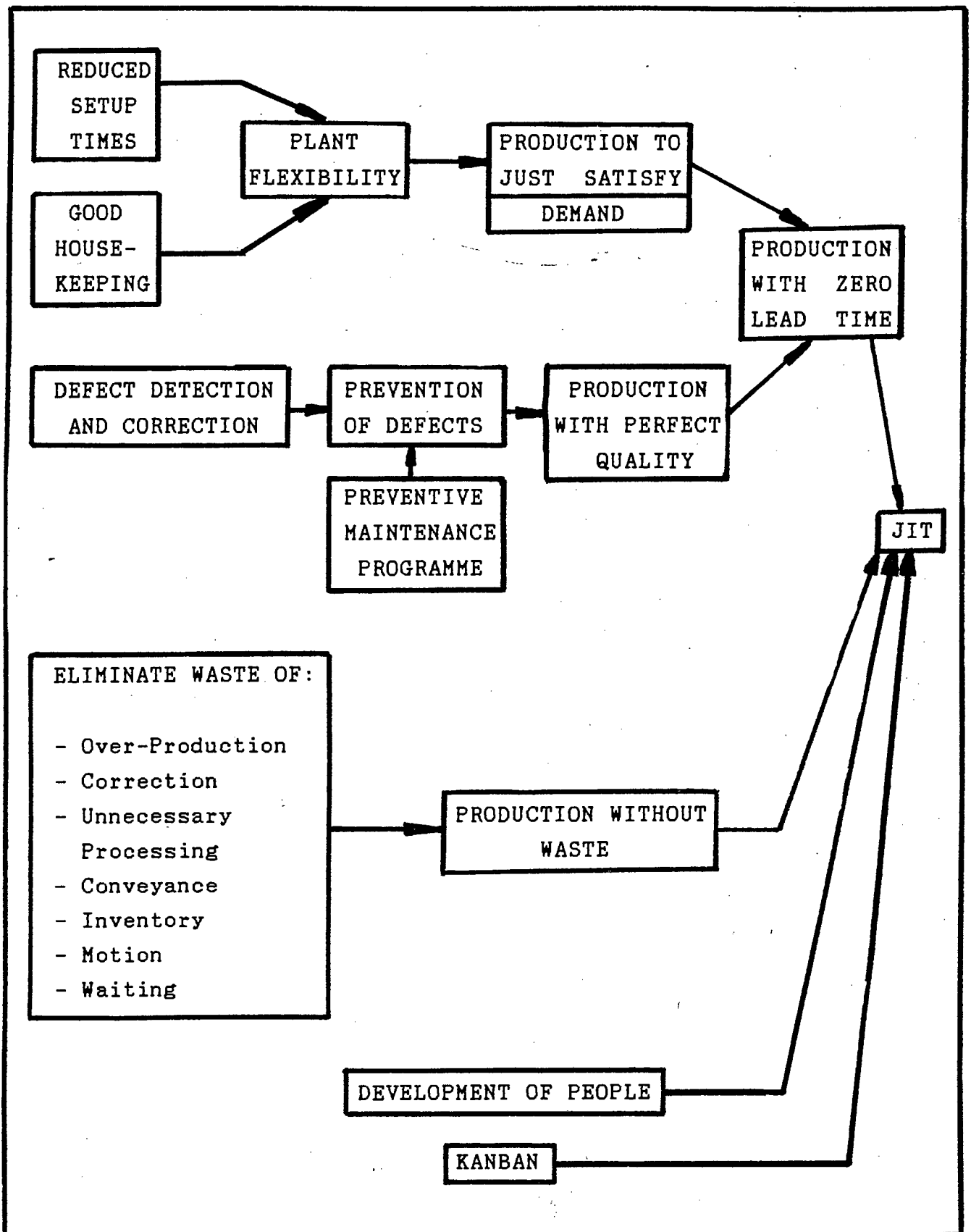


FIGURE 3.3 : An Overview of the Main Concepts in JIT Production

CHAPTER FOUR
IMPLEMENTING A JIT PROGRAMME - A GUIDELINE

Although it is important to know what JIT is and the benefits that can be obtained from implementing such a programme, Andrew maintains that there has been little put forward as a guide to the manufacture wanting to do this.

This chapter aims to set down general guidelines for JIT implementation. It is difficult to describe an implementation programme in terms of hard and fast rules due to the broad nature of the topic. Added to this is the fact that a manufacturer may want only to implement certain aspects of JIT, such as reduced setup times, purely for the benefits to be gained from that action. On the other hand, a fully integrated JIT Production system may be deemed necessary. Spurgeon summarizes the difficulties of planning and implementing JIT when he says, "Consider JIT as a concept, not a project to be scheduled and completed. Therefore don't plan it to death. Start small and build on your successes."

This guideline addresses the manufacturer embarking on a JIT programme from scratch. It does not mean that failing to put into place any one aspect of JIT means that the exercise will be a failure. To the questions, "Are there any JIT failures to report? Any cases of large expenditures on JIT with little or no return?" Schonberger replies, "None that I know of. There are some potential disasters in the making that are referred to as JIT projects, but which really are in violation of JIT's spirit of keeping things simple and flexible."

4.1 FOUR PHASES IN JIT IMPLEMENTATION

The actions to be followed in implementing a JIT programme can be classified into physical actions to be carried out, and organizational changes to be made. Four phases in the implementation process are identified, and are:

1. CONCEPTUALIZATION PHASE - this involves learning about JIT and what it means, the training of personnel, planning for both the long and the short term, and any modifications to the organization structure.
2. PREPARATION PHASE - this phase is aimed at gearing the factory for the installation of a pull system. Included in this should be such aspects as the revision to plant layout, attention to housekeeping, the reduction of setup times and improvements to quality.
3. CONVERSION PHASE - this is the phase where a pull system is installed in the entire plant.
4. CONSOLIDATION PHASE - involving further refinements and improvements to a plant already operating on a pull system.

Any real JIT programme cannot be introduced into a manufacturing plant in such a systematic manner, and the would-be practitioner must not be under the illusion that this is so. For example, phases one and two may even run concurrently and not be seen by management to be separate. These four phases are developed further.

4.1.1 CONCEPTUALIZATION PHASE

The main objective of this first phase is to enable the key personnel in a manufacturing company to visualize what their establishment would look and function like with a pull system in place. This is probably difficult to do if there are few people with any knowledge of JIT methods, and so it is vital that the basic concepts are studied and understood before

proceeding further.

This understanding is especially important to the top management. All aspects of the company, from engineering to accounting, will undergo some sort of change under JIT Production, and thus top management must be in a position to lead through this transition period.

The implementation team are the people who are responsible for, and who will actually carry out, the necessary changes on the plant floor, and so will need the most detailed preparation. This is especially true if they are to be in a position to help guide the floor workers through confusing changes. The team should comprise different specialists from production planning and control, manufacturing and engineering. A book knowledge of JIT is not sufficient for the implementation team members. A training programme, perhaps combined with first hand experience on the shop floor of a company with a successful JIT system, is necessary. This training and education should be carefully thought out, as the success of it will have a long-term effect on the overall JIT programme.

It is important that the workers in a factory be educated about the new concepts which are to be applied, and how the application of the new techniques and methods will affect their working lives. The shop floor workers will be the ones to work first-hand with the new system, and if they are confused and do not understand, JIT will not be accepted very readily.

As is the case for the implementation team, a training programme should be devised to suit the particular requirements of the shop floor worker. This training may take the form of formal lectures, or informal sessions by foremen, but however they are conducted, all concerned must be made ready for the introduction of JIT.

The conceptualization phase is the stage not only when education occurs, but when planning of both short and long-term actions takes place. This planning will cover all areas of an organization, including maintenance, purchasing and the design

function. The selection of a suitable pilot project (see SECTION 4.2), the setting of long-term goals and the modification to the organization structure should be considered and formalized.

It is impossible to completely plan a project of this nature from start to finish, but people within the organization should at least have clearly defined goals, superimposed on some sort of time frame.

4.1.2 PREPARATION PHASE

The preparation phase is probably the first time when "something can be seen to be happening in the factory". This second phase is aimed at gearing the factory for the installation of a pull system. Andrew, in his paper describing the implementation of JIT programme, calls this the Processing Stage, or the period in which processing improvements are made.

There are twelve elements of production which must be considered and attended to in this phase. These are presented below in an order of implementation suggested by Greene. It is stressed though that this will vary from situation to situation. The elements of production to be considered are:

1. Workplace organization and housekeeping.
2. Quality improvements through process capability improvement.
3. Reduced setup times and frequent setups.
4. Reduced lot sizes.
5. Preventive maintenance.
6. Incremental inventory reduction to reveal problems.
7. Reduced space for less material travel distance and improved visibility; cell manufacturing where possible.
8. Multifunctional workers.
9. Excellent preparation for production.
10. Levelling the schedule.
11. Balanced operations.
12. Material handling.

1) Workplace Organization and Housekeeping

Organizing a workplace for good housekeeping is important for a number of reasons. First, as material begins to flow quickly through the factory in small lots, it becomes increasingly important to be able to locate parts or containers of parts rapidly. Parts should thus be allocated a specifically marked location.

Tools and attachments should also be allocated a specific place. Organization of these locations for quick and easy accessibility is important. Equipment should be replaced as soon as possible in its correct position. This helps to reduce setup times and eliminate searching for tools.

The introduction of a set of work rules may also be useful at this stage. Such an aid helps direct attention to the importance of layout and the organization of the workplace.

2) Quality Improvements Through Process Capability Improvement

This element, the essential element of Total Quality Control, requires the development of various systems. A system of feedback should be established whereby, if a process goes out of control or defects occur in production, the floor worker should have the authority to either correct it immediately or to summon help if he is unable to do this. Efforts should be made at "defect proofing" machines and processes, and control tools, such as Pareto charts and statistical methods be introduced (if not already present). All these are aimed at improving the production process and achieving the goal of zero or reduced defects.

3) Reduced Setup Times and Frequent Setups

Setup times should be reduced. This should be done systematically, beginning the exercise with either one machine or a group of them at a time. Reduced setup times have the greatest influence on the ability to process in small lot sizes.

4) Reduced Lot Sizes

Lot sizes are related to the amount of material handling in a plant, the nature of it, and the distance travelled between work centres. Practical ways of reducing these lots should be looked for.

5) Preventive Maintenance

The establishment of a preventive maintenance programme is important if production levels are to be sustained or increased, and there is to be no increase in defect levels.

6) Incremental Inventory Reduction to Reduce Problems

By reducing inventory, the major reasons for requiring excess inventory will become obvious and can be tackled and solved. Inventory can be classified as active, for which a customer demand is anticipated in the future, and inactive, for which there is no anticipated customer demand. A first step is to classify all inventory accordingly and dispose of any inactive material. An overloaded master schedule, which requires more material than the company is able to utilize, is also a cause of excess inventory.

The simplification of the product structure helps to reduce excess inventories and lead times. There should be on-going education concerning the necessity to reduce inventories. If this is not so, then any reduction will be shortlived.

7) Reduced Space

Plant layout should be attended to, and although only mentioned at this point, it is considered by some to be the foundation of JIT. By moving workstations closer together, waste resulting from large transit times, queueing time, transit inventory, queueing inventory (from unsynchronized operations), excess space, and time between the occurrence and discovery of defects is reduced considerably.

Cell manufacturing is one way of reducing this space. In small manufacturing companies, machines may already be placed as close together as possible. In this case, advantage should be taken of these short flow paths, and the key in this case is not to re-locate equipment, but to try to increase its flexibility.

8) Multifunctional Workers

Worker flexibility is required for a successful JIT programme. Workers should be rotated, enabling them to increase their skills and abilities. This will make them as adaptable as possible and the manufacturing process is more likely to have an operator available at a crucial moment. Rigid job descriptions are the opposite of what is being aimed for here.

9) Excellent Preparation for Production

Preparation for production should be excellent if large problems are to be avoided. All functions, from engineering to purchasing, should prepare thoroughly and on time.

10) Levelling the Schedule

A production schedule should be set up for uniform usage over a specific period of time. This will involve not only production, but also such activities as marketing and engineering. For the assembled product, this scheduling will involve a pre-planning of volumes and sequences in final assembly. The supply operations must be levelled and sequenced to mesh with the final assembly.

11) Balanced Operations

With uniform material use, such as in a repetitive manufacturing environment, work centres should be balanced so that cycle times are the same for each operation. A fully operational pull system almost completely guarantees this fact, but nevertheless the work centres must be prepared. Bottlenecks must be ironed out as far as possible. The balancing of

operations in a non-repetitive environment is more complex, but improvements can still be made.

12) Material Handling

Material handling methods in a JIT environment are important. Handling should be reduced to the minimum possible, and to a large extent this will have been done while conducting the factory through the other eleven elements of this phase. Innovative techniques for reducing or easing handling should be looked for, with the goal of eliminating as much waste as possible from this source.

Summary

Although the twelve elements of production to be attended to in the preparation phase have been listed separately, they are in reality all interlinked. By moving workstations closer together, operations will have to be balanced more accurately, and material handling will be reduced due to the shorter transport distances involved. This is just one example of the interdependence of these elements.

Needless to say, some of these elements will be more easily applied in one manufacturing environment than another. Thus, they cannot be strictly attended to as given. Rather they should serve as a guide to what needs to be considered when gearing a factory up towards the installation of a functional pull system. Phase Three, the conversion phase, is now described.

4.1.3 CONVERSION PHASE

The timing of the conversion phase is critical, as usually much confusion is caused in the process, and it is difficult to function for long with a mixture of pull and push systems in place.

The emphasis in converting to a pull system should be placed first and foremost on the manufacturer concerned. Only when his in-house pull system is functioning properly can the suppliers

be included. In dealing with suppliers, efforts should be made firstly to reduce excess inventory from them, with the goal being that they may only supply raw materials or parts on receipt of a pull signal. Deliveries should be frequent and in small batches, with the requirements for each day's production delivered daily. Suppliers should be as few in number as possible, and every effort should be made to work with them to improve the quality of their parts where possible.

When a factory converts to a pull system, a prime consideration is the number of Kanban cards to be issued (in the case of a dual card system). APPENDIX D details the method of calculating how many cards are required. But whatever the Kanban, be it a marker, a signal, a painted square or even just an empty container waiting to be filled, their purpose initially is to test and refine the organization with them in place. The stockpoints, signal methods and so on are all tested and refined. Along with this are the constant improvements to be made in the case of materials handling, layout and reductions in setup times.

It takes an enormous amount of work just to get a basic pull system up and running. There are also the refinements to be made to such aspects as reporting and accounting systems. This work takes concerted effort by all personnel, and once begun should be completed as soon as possible to avoid too much confusion.

As with the other phases of a JIT implementation programme, the type of pull system installed will depend on the type of manufacturing and the particular company concerned. Flow production is most suited to the pull system, but manufacturers in batch environments are discovering its benefits more and more.

A problem that may become apparent when installing the actual Kanban system is, according to Sepehri (1985), an initial productivity dip. This is because attention and effort tends to be focussed initially on overcoming the various manufacturing problems which surface. The order in which the various aspects of JIT Production, if implemented as described in this chapter,

will necessarily take care of this problem. Production problems will be solved before the Kanban system is installed and the possible adverse effect of its introduction will be lessened.

4.1.4 CONSOLIDATION PHASE

The consolidation phase comes after the basic pull system is in place and functioning, and involves the refining of the system further.

An ongoing process, it involves experimenting to reduce still further setup times, refining plant layouts, further developments with parts and material suppliers and refinements to the scheduling system. Hopefully most of the confusion will be over by now, and managers and workers alike can work together to improve productivity even more. It is not good to sit back with the attitude that all is now complete and the goal of stockless production has now been reached.

4.2 SELECTING A SUITABLE PILOT PROJECT

It is impossible to implement JIT in the whole factory at once, and so the selection of a suitable pilot project is necessary as a first step. This pilot project may focus on a department, a group of machines, or a production line, but whatever the project it should serve two purposes, and be representative of the type of problem likely to be found when implementing JIT in the remainder of the plant.

The first purpose that the project should serve is to highlight potential implementation problems and enable all concerned to learn about the new approaches and techniques. The project may be treated as an experiment from which various conclusions may be drawn. The second purpose of the pilot project is, especially if it is a small one, to boost morale. JIT's benefits are shown quickly and people are won over to the new way of thinking. They then begin to work together as a team.

The pilot project may be initiated several months ahead of the main project, and during this time planning proceeds for the

implementation of JIT into the rest of the factory. The sequence of actions which have to be followed, and which are necessary for JIT production, can be tried out and adapted to the particular manufacturing plant concerned.

4.3 DATA ACQUISITION AND PRODUCTION ANALYSIS - A PRE-REQUISITE FOR JIT

Having chosen the pilot project and, either before or concurrent with any planning for JIT, it is necessary to review the present production process in that facility. The purpose of the review is twofold; first to initiate the thought processes as to where setup improvements may possibly be made, where bottlenecks are occurring and so on, and second to gather data so that comparisons between the old and the new may be made at a later stage. This data should include, if possible:

- inventory levels.
- inventory by operation.
- lead times.
- equipment speeds, outputs, demand rates and utilization.
- routing.
- machine downtimes and causes.
- purchased materials by commodity (Rand volume, number of vendors, inventory turns).

The data will help to pinpoint trouble areas. For example, it will help to highlight which machines break down the most, or emphasize a bad materials flow problem. Any changes should be made with a firm knowledge of what is presently wrong with the system. A degree of experimentation is involved in setting up for JIT, but without this data, changes may occur for the worse and management will remain unaware.

FIGURE 4.1 summarizes the steps that are required when implementing JIT Production in a manufacturing environment. The chapter attempts to outline the major stages without, at the same time, being too specific. There is no substitute for first hand experience, and so as a company proceeds up the learning curve, the goal of a total production system comes closer.

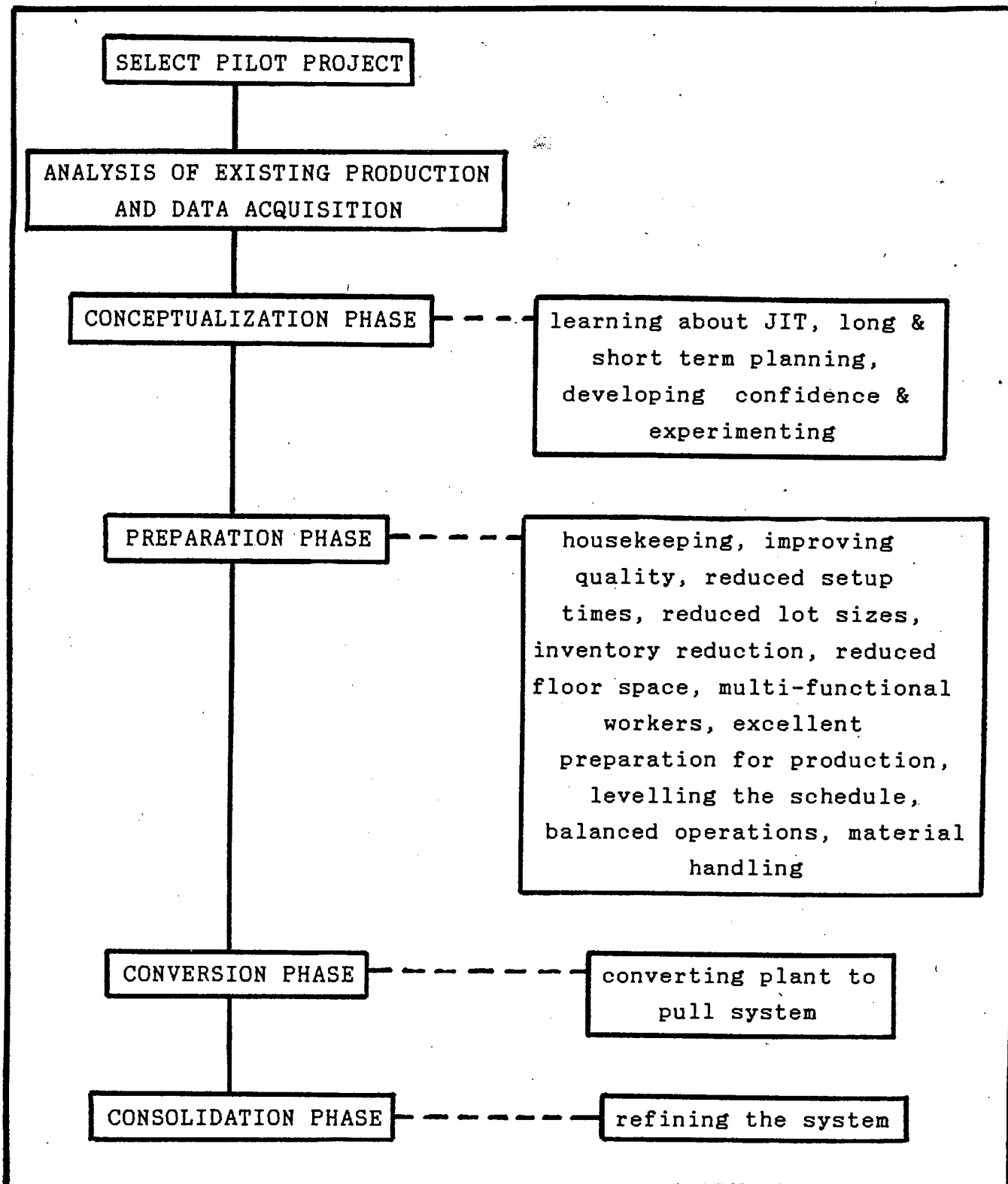


FIGURE 4.1 : Steps In Implementing a JIT Programme

CHAPTER FIVE

PROBLEM IDENTIFICATION PRIOR TO JIT IMPLEMENTATION

Chapters Three and Four respectively were concerned with briefly outlining the fundamental concepts behind Just-In-Time Production, and describing in broad terms how it may be introduced in a manufacturing plant from scratch. Two shortcomings of the material thus far presented are apparent. The first, is that although certain accepted JIT techniques are more easily applied to the small manufacturer than the large, those techniques are not made clear. The second shortcoming is that of the vagueness of how exactly to go about converting a plant to function by the methods called for under JIT Production.

The objective of these remaining chapters is to attempt to identify those aspects of JIT which are more readily applied by the small manufacturer. In addition an outline of how JIT was introduced into a small air and fuel filter manufacturing plant is presented, on which the research is based. It is realized that although the situation and solutions described are particular to that manufacturer, the approach to the project will give a deeper insight into the area of setting up for JIT Production.

5.1 BACKGROUND TO THE PROBLEM

The last few years had seen the adoption of certain JIT Production techniques by the filter manufacturer throughout areas of the plant. These techniques had enabled significant productivity increases to be achieved. The plant press shop, which manufactured all the pressed parts necessary to make up an air filter body, had thus far remained unaffected by these changes. Consequently it was becoming of grave concern to management; firstly because of the existing production bottleneck it was causing, and secondly, as a result of the huge increase in demand for air filters (including new designs), it was necessary to increase the press shop capacity without, if possible, having to resort to the purchase of further presses. The redesign of this press shop; its material handling methods, layout, tooling storage etc., based on JIT

Production methods, was considered by management to be the only way of eliminating these production problems. For the purposes of this research, this redesign was taken to represent the pilot project.

Chapter Five describes the production situation existing in the press shop area prior to changes being made. The analysis highlights the main problems that were found, with regard to such aspects as production methods, materials handling and press setups. In addition, comments are made on the adequacy of any training prior to the introduction of those JIT techniques to date. Other problems encountered in the implementation of JIT are mentioned, with an aim to improve on them if possible in the pilot project.

5.2 TRAINING OF PERSONNEL PRIOR TO JIT IMPLEMENTATION

It is suggested that inadequate or inappropriate preparation for JIT is one of the major reasons contributing to a programme which, at best, takes a long time to show any results, or at worst is unsuccessful. Such a lack of training was found to be one of the major causes of an initial JIT programme not meeting expectations at the filter manufacturer. No training schemes had been established at all, and a resistance by workers to change to work by the new methods was obvious. Management, though, and to a lesser extent supervisory staff, were well versed in the concepts behind JIT Production. Visits to outside companies by some, to observe established and successful JIT systems, had contributed towards their knowledge.

The approach thus far to implementing JIT in the factory had been one of the imposition of new ideas by such functions as engineering and production, and by management decision, with very little input by the floor worker. These new ideas were seen in the form of revised production methods, revised plant layouts, redesigned equipment etc. No use had been made of formalized implementation teams to accomplish set objectives.

The existence of this problem, however, did not mean that management was unaware of it. They had recognized their

shortcomings and were open to suggestions and improvements. The need for a training programme, tailored to the specific requirements of the people concerned, had now been recognized.

5.3 PRODUCTION PROBLEM IDENTIFICATION

5.3.1 EQUIPMENT AND FLOOR LAYOUT

At the time of the study, the press shop equipment consisted of a number of presses of various sizes, as well as a guillotine. Their floor arrangement is shown in FIGURE 5.1 below. Included in the press shop area is a gas welding line and associated conveyor system. This line formed no part of the study, except that the floor space occupied by it was to be taken into account. Die storage was on racks running down the centre of the floor, and a multi-tiered rack situated along one wall kept WIP off the floor area. Sheet steel storage was on racks situated adjacent to the guillotine. A small machine shop was situated at the end of the building and was to become available later due to building extensions.

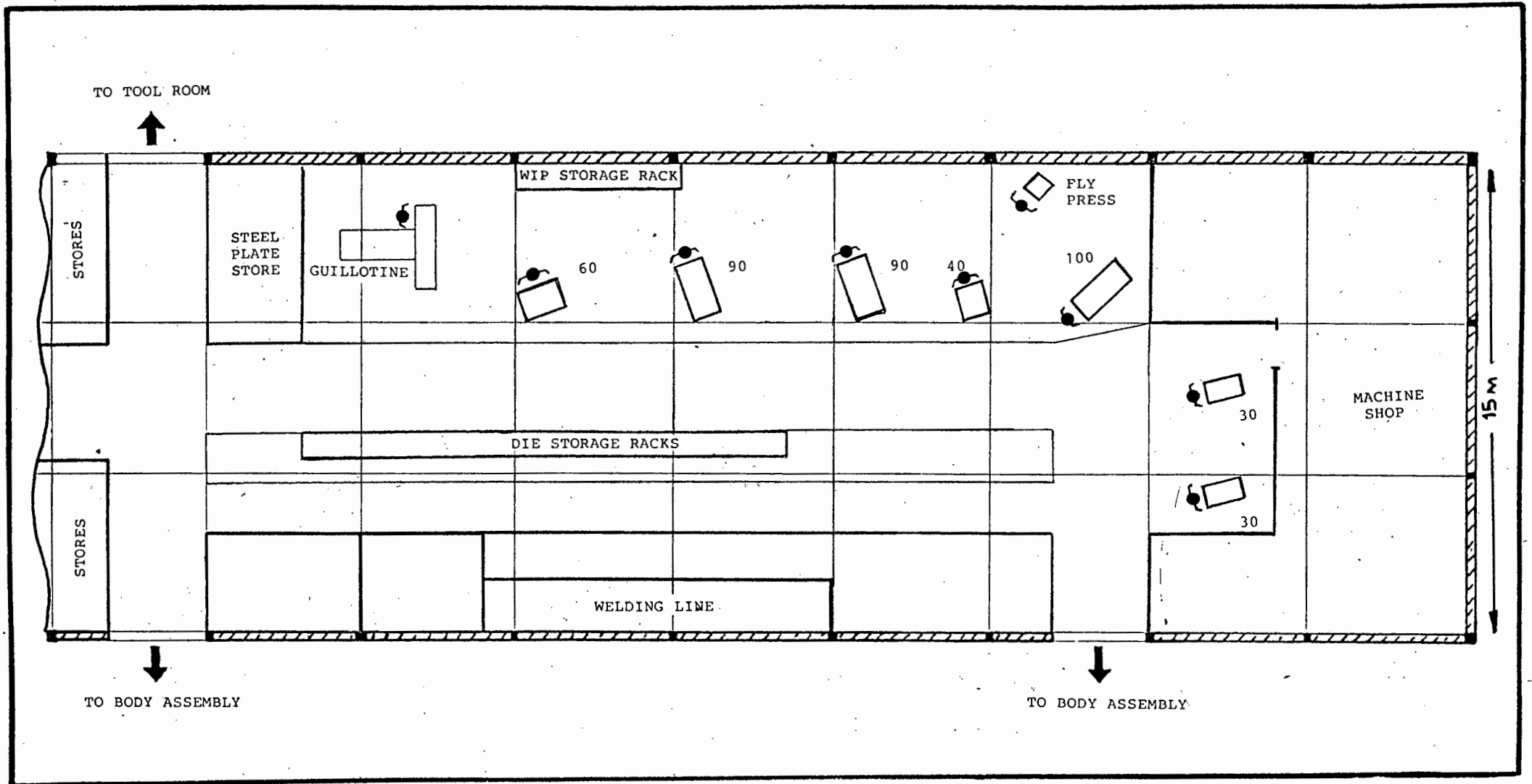


FIGURE 5.1 : Press Shop Equipment and Floor Layout

5.3.2 HOUSEKEEPING

Housekeeping was found to be generally rather poor. A concerted effort by everyone had resulted in significant improvements, but the problem of clutter still remained. The cause was a combination of poor materials handling methods (raw materials, Work In Progress and waste), a poor machine layout, no clearly defined storage and WIP areas, and other factors. Material was thus placed wherever there was space, resulting in poor accessibility to the various presses.

5.3.3 PRESS TOOLING AND DIE STORAGE

Miscellaneous equipment such as parallel blocks, buffers, clamps and platens were stored on the same rack as the dies. Tool storage (spanners etc) was in steel cabinets, which were bolted to the wall.

For identification purposes, each die was colour coded according to the make of vehicle for which it produced parts, and was stamped with the part number and the number in the sequence of operations necessary to manufacture that part. Dies were then grouped according to these colour codes. No specific position was allocated to any one die.

Tool and die storage in the above manner presented a number of problems hindering quick setups. The first is that, with no die being stored in exactly the same place all the time, it often took longer to locate the next tool than it should have, as the tool setters had to rely on remembering where they had placed the various dies on the rack.

The retrieval of those dies on the upper levels of the rack was often awkward. A small trolley with a platform that could be raised and lowered was used for this purpose. This necessitated the use of two people for the job of loading the heavier dies onto the trolley, moving the trolley to the press concerned, and sliding the die onto the press table.

Even though specific places were allocated to house the various tools, the cabinets were not always used and it was observed that it was often necessary to search for equipment prior to performing a setup.

The method of colour coding each die also had faults. Although by simply looking at the colour of the die one could tell the make of vehicle on which the finished air cleaner was used, one could not tell at a glance on which press the operation was to be performed. As an aid to quick setups, the ideal situation is one where one particular operation is only ever performed on one machine. Process sheets had thus been drawn up to aid the tool setters in allocating a die to a particular press, but this still was not ideal. An added complication was that various operations could be performed on a number of machines, and this was done in practice to keep presses from standing idle.

5.3.4 PRESS SETUPS

A typical press setup procedure was observed and is described:

1. Stop press.
2. Collect together spanners and unbolt old die from press.
3. Slide die off press and onto transport trolley.
4. Push trolley to storage rack, store die and retrieve next one. Transport to press.
5. Slide die onto press bed and bolt into place. If necessary, use parallels and/or platens to set die height, and set buffers if required.
6. Adjust safety guard, safety stops etc. and produce first off samples for Quality Control.

These setup operations varied in length from 20 to 45 minutes, depending to a large extent on which operation ran before (how complex the old die was to remove) and the nature of the next operation. The length of the setup was also found to be affected by who carried it out.

Various factors were identified which contributed to setup

times that were longer than necessary. These included the fact that internal and external setups had not been identified and separated and that die heights were not all standardized (requiring the use of parallel blocks to raise them if necessary). Press safety and adjustment stops were found to be awkward to set, and it was found that tools could sometimes not be located quickly.

5.3.5 MATERIALS HANDLING

Materials handling, both of the pressed parts and the sheet steel, from which the components were made, constituted one of the biggest problems in the press shop.

Steel plates of various grades and thicknesses were brought in, and it was from these plates that all the parts required to make up a complete air cleaner assembly were pressed. Delivery was in strapped and palletised bundles of approximately 20 sheets a time. These were unloaded with a forklift and stacked, still on their pallets, on the floor next to their storage racks. Two people then placed the sheets individually in the racks. Before proceeding through the presses, these sheets were cut into blanks on the guillotine. The process of cutting the plates into blanks required two people, who had to lift each plate out of its rack, place it on the guillotine cutting table, and feed it through the blades. Cut blanks fell onto either a pallet or into some sort of container for transport to the die for pressing.

Apart from the danger of moving the heavy bundles of sheet steel with undersized forklifts, there was the waste of needing two people just to unload and stack the individual sheets, or to load them onto the guillotine table before cutting. There was also the hazzard and housekeeping aspect of leaving bundles of sheets lying on the floor. Individual sheets were sometimes damaged due to overtight strapping. In order to get the maximum number of parts from each sheet, some of the blanks cut on the guillotine, and from which smaller parts were obtained, were up to 2450mm long. This resulted in awkward handling procedures, and obviously blanks of this length required a lot of space;

both for storage and while being processed.

Press shop work in progress was moved from press to press in a variety of containers; the container depending on the size and number of completed or part-completed pressed parts. These containers consisted of large wooden bins, wire bins on wheels, pallets, metal bins and even cardboard boxes. A hand pallet trolley was used to move the bulkier and heavier containers.

There was no standardization of container size, and no fixed number of parts per container. This resulted in parts being counted many times as it was not always known just how many were in any one container. The larger containers were difficult to handle and manoeuvre around the shop floor. There were no formally designated areas for work in progress storage, and much clutter occurred because of this. Waste removal was a problem, both in the press shop and in the rest of the plant. Small bins on wheels had been introduced for this purpose, and had been successful to an extent, but were still far from satisfactory.

5.3.6 LOT SIZES

It was found that a production run tended to be larger than was actually necessary, leading to excess work in progress or requiring a quantity of the finished pressed parts to be kept in storage.

The deciding factor in sizing a production run was found to be a combination of the length of the press setup time and the number of parts obtainable from each steel sheet. Whole sheets would be processed at a time, resulting sometimes in excess to requirement. For example, if a full sheet yielded 32 parts, two full sheets would be processed for a requirement of 50 pieces, leaving 14 extra units. This excess would then go into storage. Also, because of the long setup times, batches tended to be as large as possible to cut down on the setup effect. Excess work in progress from these large batches contributed to poor housekeeping.

5.3.7 PREVENTIVE MAINTENANCE

No preventive maintenance programme existed, and the policy tended to be one of breakdown maintenance. Any work that could not be done in-house was subcontracted. A weekly inspection of the presses was performed though, and the machines oiled and greased as necessary. The press operator was responsible for cleaning his machine after use. It was not deemed necessary by management to initiate a preventive maintenance programme.

5.3.8 MATERIAL FLOW PATTERNS

The machine layout in the press shop, was inadequate for a number of reasons. One was that for a particular part to be pressed, it was sometimes necessary for the component to move from a press at one end of the press shop to a press at the other end, and then back to the beginning. (A typical flow pattern, for a number of parts, is shown in FIGURE 5.2). Not only did this involve large travelling distances, but the material handling involved compounded the problem of long lead times and high work in progress inventories.

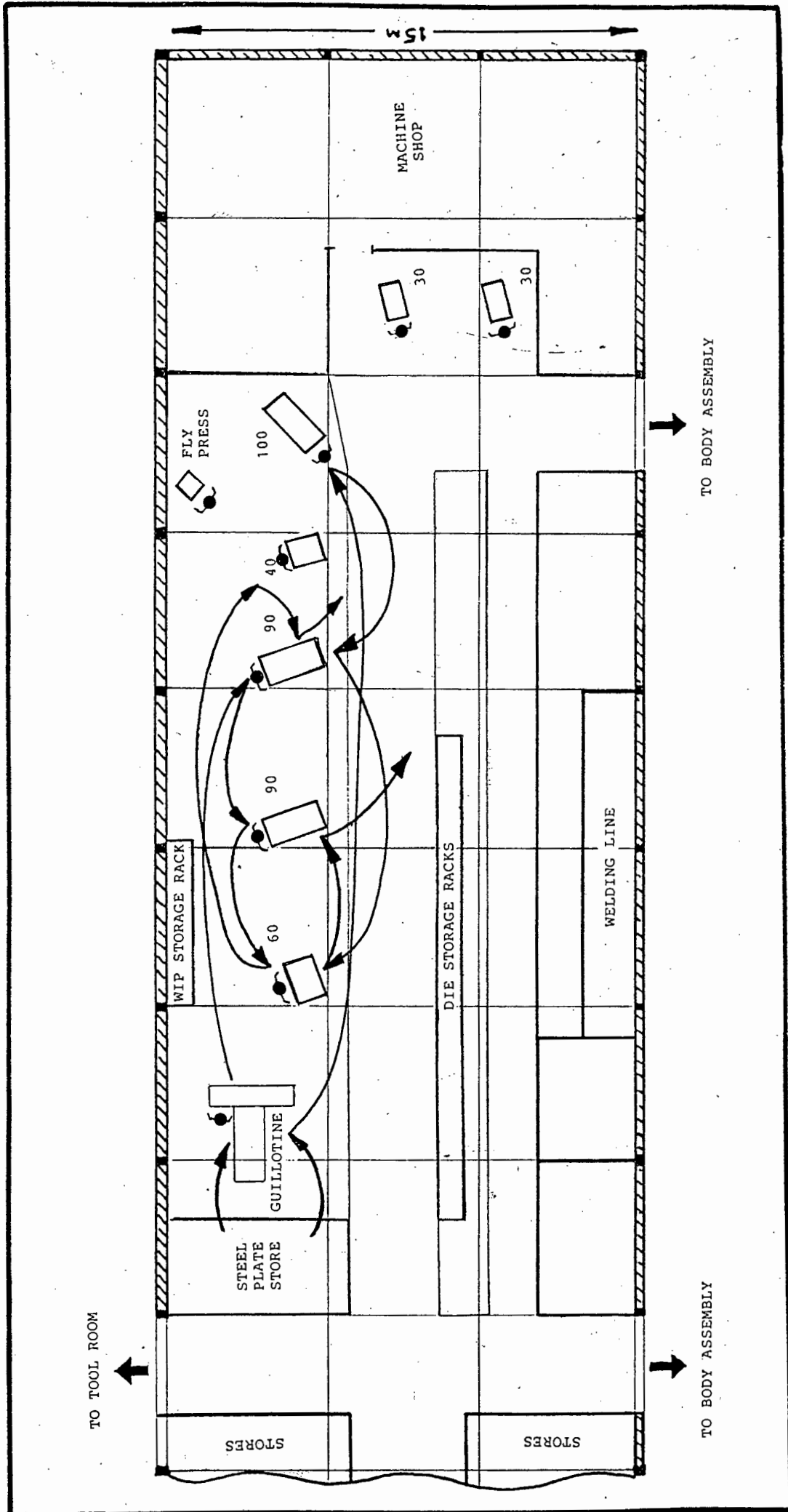


FIGURE 5.2 : Typical Travel Paths for a Number of Parts

5.3.9 OTHER PROBLEMS ENCOUNTERED IN JIT PROGRAMME TO DATE

A number of other problems were highlighted while investigating the problems in the press shop. A major one was that of the ineffectiveness of the existing Kanban system.

Kanban cards had been introduced ahead of their time, and instead of performing their intended function of controlling production and highlighting problem areas, they had compounded problems. The biggest was their lack of acceptance by shop floor workers, who had no understanding of the purpose of the card and often did not even bother to use them at all. The cards had also been introduced before a number of production problems had been sorted out. Included in this broad statement are the problems of long setup times, poor material handling, inadequate stock control and so on, which have already been mentioned.

5.4 DATA ACQUISITION AND ANALYSIS

5.4.1 LEAD TIMES

An investigation was carried out to determine the approximate time it took for a batch of components to move through the press shop, from the first operation to the last. Cards were attached to the batch, on which was stated the batch size, part number, time at which processing started, and the time the batch was completed.

Lead times varied depending on the component and batch size, but were found to be very long in relation to the time actually spent on processing the components. Most of this extra time was consumed in waiting for a press to become free, with a smaller amount of time taken up in handling.

5.4.2 EQUIPMENT UTILIZATION

In order to examine the utilization of the various pieces of equipment in the press shop, a program was written using the Lotus 1-2-3 spreadsheet package. The aim was to identify which presses were being used the most often, which were breaking down the most often, and on which presses the most time was being spent on setup. All this information was able to be displayed in either graphical or table form for easy use by supervisors and management.

Before beginning the program, a quantity of data had to be collected and sorted. Bills of Materials (BOM's) were obtained for each finished product, and for each pressed part in the BOM, the following information was compiled:

- operations required to complete the part.
- time to perform each operation.
- the machine that the operation is performed on.
- setup time on that machine for the particular operation.
- average lot size for each part.

To run the program, certain data was input, and a printout typical of the one shown in FIGURE 5.3 was produced. A full description of this program is given in APPENDIX E.

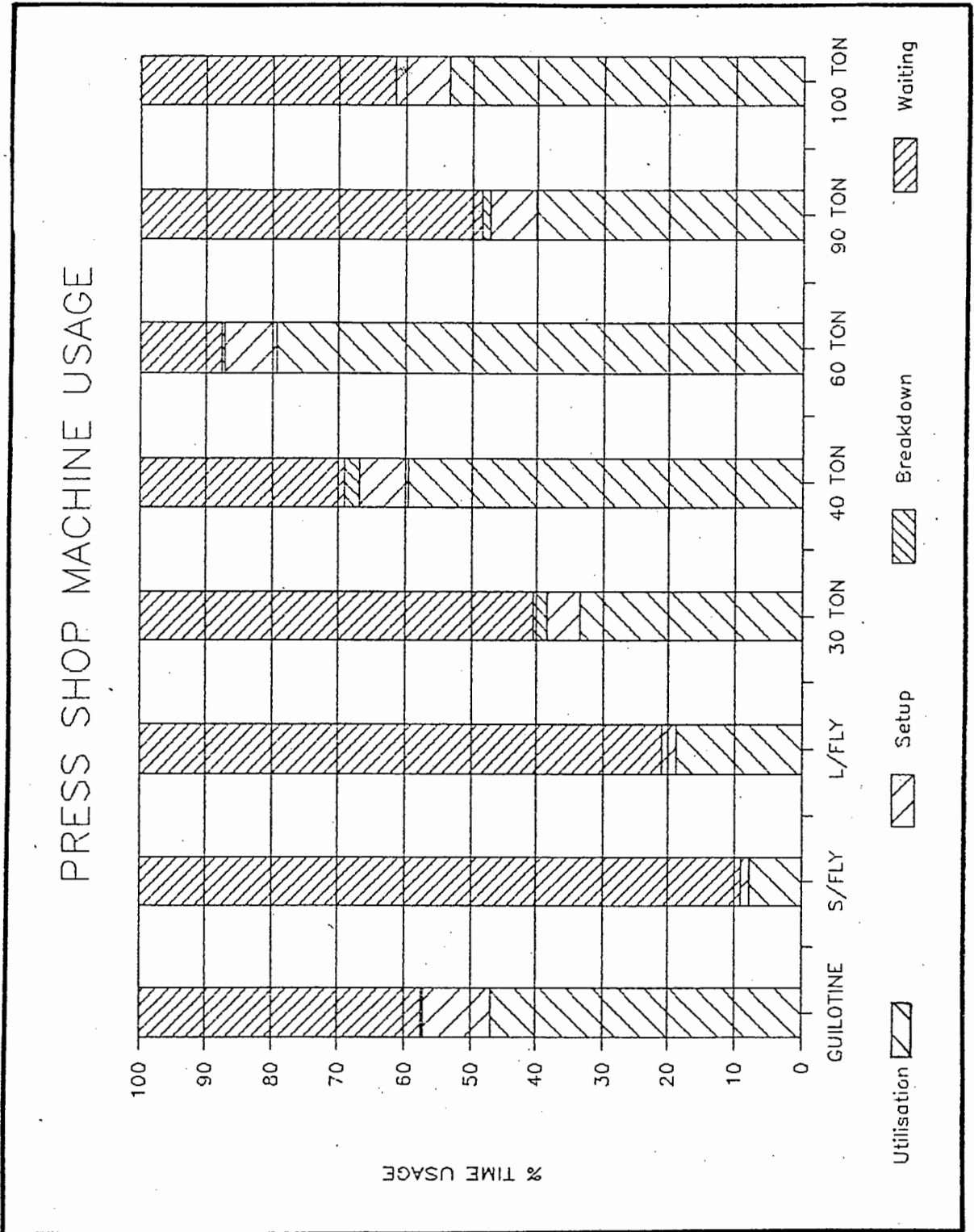


FIGURE 5.3 : Press Shop Equipment Utilization Output

Findings of the Study

The information obtained from the study enabled production personnel to observe in a simple visual form how the various machines in the press shop were being used. It emphasized bottleneck machines and procedures eg. which of either setup or breakdown was taking up undue time, thus enabling further efforts to be concentrated in the right areas.

A program of this nature should be used not only as a study tool but as a "what if" analysis tool. It is easily expandable to take into account new products, and times may be updated very simply in the light of new information. It is with such an analysis tool that a production facility, such as that of the press shop, may be balanced and honed to the maximum efficiency.

The importance of basic work study methods must not be overlooked, and it is important for any manufacturer wishing to go the JIT route to carry out such a task. Obviously, the nature of the investigation will vary from plant to plant, but by making a thorough examination of the production problems to be found at the plant, and by formalizing these problems (much as was done in this chapter for the filter manufacturer), management may obtain a clearer vision of just where to concentrate future improvement efforts. Such an analysis may help too, to highlight which problem areas are the most critical, and where potential problems might occur.

A study such as this should not only be carried out by management, acting, as it were, as an impartial observer. Shop floor workers have their part to play. They are after all the ones who work with production problems every day and are thus the closest to them. Their ideas and views should be continually sought, perhaps through the supervisors as intermediaries. It is only by talking to people that one can find out what the true situation is. Armed with an basic analysis, production problems can begin to be tackled and solved.

CHAPTER SIX

PRODUCTION IN A JIT ENVIRONMENT

Having examined the concepts behind JIT, and the problems existing in a production facility prior to its introduction, the application of these techniques in actual practice may now be outlined. The outline of the training programme, the setup time reduction programme, and the preventive maintenance programme intended to serve as a detailed guide as to how to tackle the problem, and may be applied in any manufacturing organization.

6.1 THE JIT TRAINING PROGRAMME

The need for an adequate training programme is vital to the long-term success of a JIT effort, and its importance should not be overlooked. The broad nature of JIT will mean different forms of preparation for the various people in the factory.

6.1.1 THE IMPLEMENTATION TEAMS

The selection of suitable implementation teams is the first step in the training process. Team members should be drawn from managerial, supervisory and factory personnel; members who will be able to contribute specialized knowledge. Obviously the size of the factory will determine the size and number of the implementation teams, but for each, a project leader should be allocated. The specific rôle of each team should not be underestimated, and the members made aware of this.

6.1.2 THE TRAINING STAGE

Having selected the implementation team, their preparation for the task ahead should then be carried out. The major components of JIT Production need to be explained. Discussion sessions focussing on the application of these ideas to a particular area of concern help to engrain them. For example, workplace organization, setup reduction, and tool management. These sessions may be used for the identification of waste areas too.

The preparation of the implementation team for the task ahead must be done thoroughly if each team is to be in a position to guide the floor worker through the process of change. A series of training manuals, covering the major aspects, aid this task.

6.2 MACHINE LAYOUT AND MATERIALS HANDLING FOR JIT PRODUCTION

The layout of machinery on the shop floor has one of the greatest impacts on a number of aspects of production important in a JIT environment. The most significant of these are that, by moving workstations closer together, several forms of waste and cost may be eliminated at once. For example, total transit time may be greatly reduced, as well as transit inventory, queue time and inventory, space, and the time between occurrence and discovery of defects. Plant flexibility and throughput times may be increased and decreased respectively.

A good layout will have an effect on the overall quality of housekeeping too. Work in progress (WIP), tools, dies, scrap bins and the like will have been given consideration to, and specific places will have been allocated to them. This will mean that employees and shop floor workers will know precisely where to find anything when required, as it will always (hopefully) be found at that particular place.

Finally, a good floor layout will have taken into account WIP movement routes and handling methods, scrap removal procedures and routing of the scrap bins, and handling and routing of raw materials in whatever form they are to be found. From the above, it can be seen why Schonberger deems a good workstation layout to be the "foundation of JIT".

In terms of product flow, the ideal layout is a straight line all the way through production. In reality, though, there are factors which will prevent this from happening. A factory wishing to convert to JIT Production will most likely have already set up their production according to department (eg. paint shop, machine shop or final assembly area), and thus the difficulty of rearranging the entire factory layout, along with

probable space restrictions, will mean that the company will commence its JIT programme by considering individual departmental layouts first. In time, operations may even be physically linked, coming closer to the goal of a straight line layout.

Before revising an existing plant layout, the objectives required of the new arrangement should be stated, keeping in mind long-term goals and requirements. A number of objectives that may be used are:

- To have the shortest possible transportation routes between processing machines.
- To have a high degree of machine utilization.
- To have a low level of WIP inventory.
- To occupy the smallest possible floor area.
- To relocate machines and peripheral equipment for reduced physical handling of material.

These objectives will be set by management or by the JIT implementation team prior to the revision.

Obviously, though, there will be constraints on these objectives which will be peculiar to the manufacturer concerned. These should be recognized for what they are and given due consideration. Two obvious constraints are the nature of the manufacturing process present (job, batch, flow etc.), and the degree of flexibility required of the machines in question. There are others. JIT methods are less suited to a job shop environment than to a flow production system, but even so it is usually possible to improve a current machine layout in an attempt to increase the flexibility of machinery and decrease production throughput times.

Thus, the first stage in revising a plant or department layout is to state the objectives of the new layout, applicable constraints, and to recognize the type of manufacturing process present (which will determine to a large extent the new layout).

6.2.1 OBJECTIVES AND CONSTRAINTS OF THE NEW LAYOUT

The study of the press shop facility at the filter manufacturer, highlighted the problems found with the workstation layout. The objectives and constraints applicable to the revised layout could then be set. This was possible after recognizing the type of manufacturing process present.

The Nature of the Production

Manufacturing was performed in batches of components, with there being no fixed quantity per batch. These batches proceeded from machine to machine, periodically having to queue if the next workstation were occupied, or having to be taken off a machine in the case of a more urgent job being required. Certain jobs could be performed on more than one machine, which was often done to avoid unnecessary waiting.

With a knowledge of the problems in the existing press shop, and an idea of how the components are processed through production, the objectives of the revised layout could then be set.

Objectives of Revision to Press Shop Layout

The following objectives were set for a revised press shop layout:

1. To obtain the shortest possible transportation routes between workstations.
2. To cut down on the physical handling of tools and dies as much as possible.
3. To make available demarcated areas for the storage of WIP.
4. To provide a layout which could be expanded in the future, and which would not grow "obsolete" as new products were added to the range.
5. To provide enough space for the storage of pallets and precut blanks if it was decided in the future to change to purchase of raw materials in this form and scrap the guillotine.

Constraints on Revised Layout

1. Limited space, with the location of the stores area being fixed.
2. The guillotine was to be positioned such that, if it were decided to remove it later and buy out pre-cut blanks, this could be achieved with little or no interference to the existing machines, and the space vacated for other purposes.

6.2.2 MACHINE GROUPING IN NEW LAYOUT

There is no one correct way of setting out machines on a plant floor. The main objective, though, is to move them as close together as possible and group them in such a fashion that there is no or little doubling back as components or finished products are manufactured.

A common method of setting out machines is by the layouts called for under Group Technology. Machines are located next to each other in a circular or U-Line layout. The U-Line layout is a step towards full automation, with the workers moving workpieces from machine to machine, walking whatever path is necessary to balance the line. The U-shaped line is particularly suited to the manufacture of one specific component or product, with production in long runs.

The locating of machines in circular layouts is more flexible due to the fact that a larger variation of parts may be produced on the same machines. Routings between the machines will be different, but none-the-less, a specific group of machines may be set up to accommodate each variation of part. FIGURE 6.1 shows the difference between a U-Line layout and a circular layout.

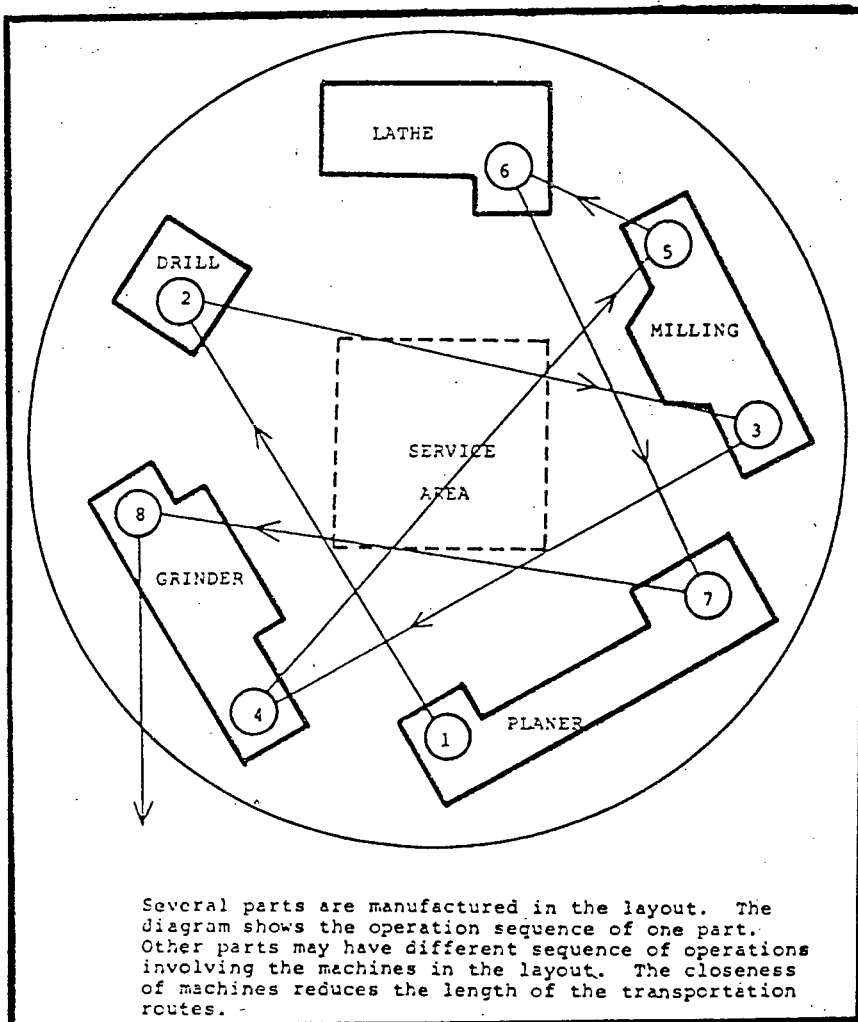
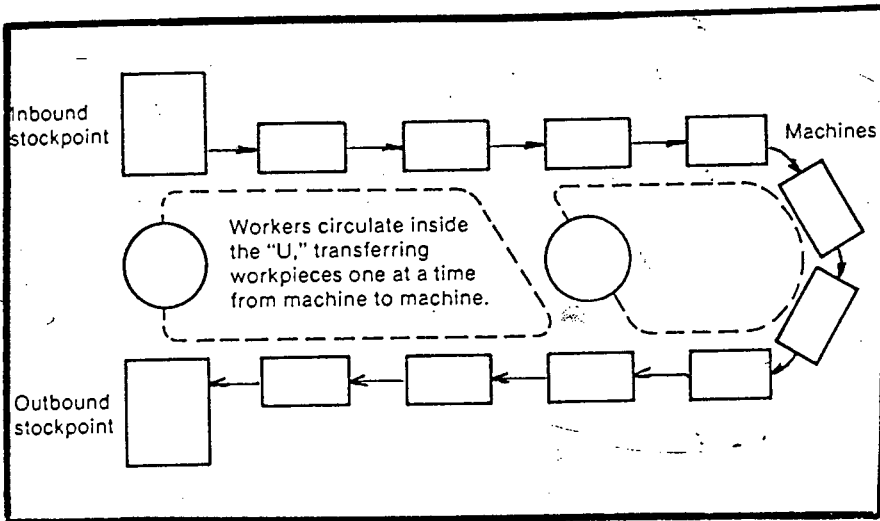


FIGURE 6.1 : The U-Line and Circular Machine Layout

Such was the variation in processes for the pressed parts manufactured, that a U-Line layout was unsuitable. A circular layout would have been ideal, but space limitations restricted such a configuration. It was found, though, that two "interlocking" circular layouts took into account all the products that were manufactured in the press shop.

Each manufactured component could be grouped into one of two groups. This grouping was achieved by making an analysis of all the components, the operations through which each part underwent and the press on which the operation was performed. It was found that the parts could be separated into those that were manufactured on the lighter presses (fly presses and 30 and 40 ton machines), and those which required the heavier machines (60 ton, 90 ton and 100 ton presses). Little overlap was found, indicating that a circular grouping of the lighter presses adjacent to a circular grouping of the heavier presses would accommodate production requirements. FIGURE 6.2 below shows the new machine grouping, and traces out a typical path of travel for a workpiece.

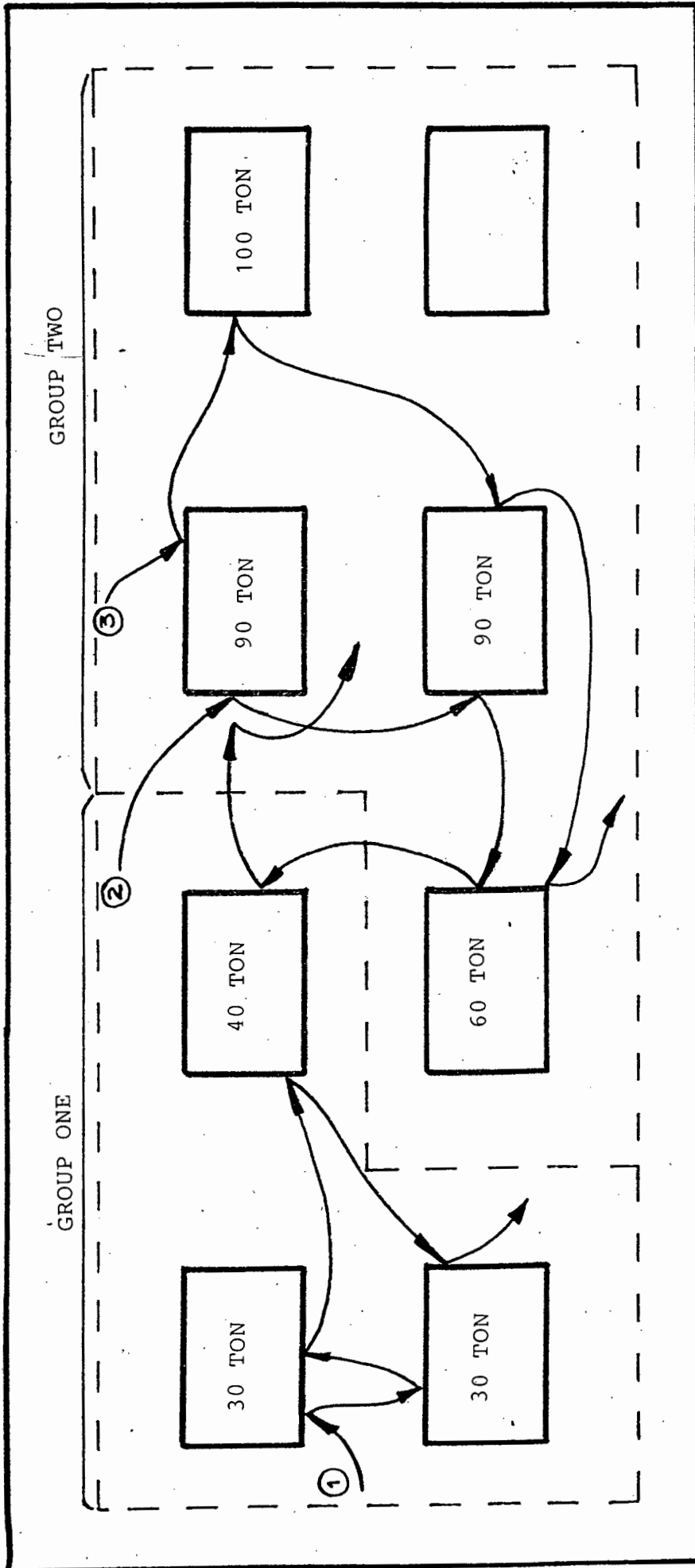


FIGURE 6.2 : Machine Grouping for Production Requirement

This layout was considered to be more suitable for a number of reasons. The first reason was that travel distances were considerably shortened as there was little doubling back of components currently manufactured. Second, with machines grouped physically closer together, there was less room for WIP to accumulate, an added incentive to try to reduce WIP inventories. Third, space was released for other purposes, and fourth, it was considered to be more suitable for the production of new products in the range (no matter what the new product, it would fall into one of the two groups mentioned. Heavier sectioned pressings would require the heavier presses, and light pressings the lighter presses.).

There is no one correct layout for workstations on a shop floor. In setting out a production area, careful consideration must be given to what is actually required of the new layout, and what constraints may limit a configuration. Thought should be given to the layout's adaptability for future expansion, as it is expensive and inconvenient to change the physical position of machinery too often. Only after this has been done should the layout be modified.

6.2.3 POSITIONING OF WIP AND TOOL STORAGE AREAS

Not only should workstation layout be modified, but due consideration must be given to suitable storage areas. These areas include a place and method of storing WIP, and a storage area for tools, dies, jigs, fixtures and the like. Inbound and outbound stockpoints should be clearly marked. In a fully operational JIT system with Kanban correctly applied, inventory between operations should be minimal and so storage space for WIP will be proportionately small. However, demarcated areas will still be required.

Again, there are no hard and fast rules about where to locate these facilities. Consideration should be given to accessibility (both for people and for forklifts, trolleys etc.) and things should be placed where they can be found first time when required. This was the case at the filter manufacturer

where, although places were allocated to store tools and dies, they were not to be found in the same place all the time.

A few simple measures would have enabled this to be the case. By modifying the colour coding, to one where a die of one colour would only ever be used on one particular machine, the ability to find a die more quickly would contribute towards the reduction of setup times. The dies used on any one machine could then be grouped on a rack and their position clearly marked. The die would always be found in this location. Similarly, the storage of spanners, screwdrivers and the like in a portable cabinet which could be wheeled between process for setups would aid in locating tools faster.

6.2.4 MATERIALS HANDLING AND PLANT LAYOUT

An important consideration in laying out any shop floor is materials handling equipment and methods. The type of equipment and methods used will affect the layout, and the layout will affect the equipment and methods used. The two cannot be separated.

In a JIT environment, it is necessary to be able to move products through the plant or work area in smaller and smaller lots, approaching the ideal lot size of one. It is also necessary to attempt to reduce the material handling involved, and part of this problem will have been solved in relocating the various workshop machines.

There are a number of ways that the material handling objectives may be attained. Four major objectives of a revised material handling system were required at the filter manufacturer. These were:

1. To cut down or eliminate the handling of large steel sheets, thereby reducing waste and eliminating the danger of moving heavy bundles of steel sheet with undersized forklifts.

2. To improve or ease the waste removal process, by reducing the size of the large blank skeletons left over from stamping out components from long strips.
3. To reduce the time wasted in counting parts in containers.
4. To simplify and ease the handling of WIP inventory by reducing or eliminating the need for forklift trucks, trolleys etc.

A simple solution to the problem was to make use of a number of containers; two sizes of which were able to accommodate all the components made in precounted batches of fifty parts.

Blanks coming off the guillotine could be packed in these batches into the containers, and these then stored for a short period or processed through the presses immediately. Identification labels on the bin would indicate the part number plus any other relevant information. The procedure for pressing the blanks into finished components would be for the machine operator (or a person dedicated solely to material handling) to collect the required number of these small bins of parts from a storage rack and carry them to a position beside his press (placing them either on the floor or on a small rack). He would then process all fifty parts in each bin through the press, placing them in an empty bin of the same dimensions when finished. Thus it would always be known how many parts were in each container, and because of their small mass (container plus parts), they could be carried around manually, without the need for a pallet trolley or forklift.

A storage rack would keep these containers directly off the floor, making use of otherwise wasted vertical space. The housekeeping would improve as a result of this, and by demarcating positions on the rack, the press operator or material handler would always know where to locate any material.

In time the system could be extended to provide for the purchase of precut blanks from the supplier, instead of the

large sheets currently delivered. The same containers could be sent to the supplier with a Kanban card, indicating the part number, blank size, material grade and thickness, and number of blanks per bin. The supplier would be informed a week or two in advance of requirements, and containers of parts delivered once a week. The guillotine would still be retained until such time as supplier quality problems had been eliminated (eg. undersized or oversized blanks), or for emergency situations.

Management had expressed doubts as to the supplier's ability to provide blanks of the correct dimensions. If they could not do so, money would be wasted as they would not be able to fit the press dies. By commencing the exercise with the purchase of a few of the parts in blank form it would be possible to ascertain whether or not the supplier could maintain the tolerances required, and work with him to improve quality. Finally, the complete conversion to the purchase of precut blanks could be carried out.

The subdivision of batches into smaller ones of fifty, each contained separately, would mean that there would be more transportation involved. However, this would be more than compensated for by decreasing transport distances (due to the new layout), enabling moves to be made more quickly and with less effort (as small batches could then be moved by hand instead of waiting for a trolley to become available), and eliminating the need to count physical quantities of WIP inventory. The dangers and manpower involved in handling the large steel sheets would be eliminated, as the mini containers of precut blanks could be delivered on wooden pallets and off-loaded directly into a storage facility using a forklift truck. And finally, the awkwardly long blank skeletons would be eliminated as they would be delivered in the form of shorter blanks from the supplier. Waste removal would thus be eased, and use could still be made of the waste removal bins currently employed. The small bins containing precut blanks are also adaptable for use on conveyors or gravity chutes if this method is chosen to move material in the future.

The difficulties of getting a materials handling system of this

nature up and running must not be underestimated. It takes time to achieve the sort of relationship with the supplier that is required, there is discipline necessary to ensure that parts are not mixed up between bins, storage procedures must be formulated, and many other factors. It is only once the random material movements present in a system are eliminated, by systematizing them and ensuring that all concerned are aware of the new procedures, that waste in manufacturing may be eliminated or reduced. This will allow the manufacturer to move closer to the goal of true stockless production.

The final proposed plant layout for the filter manufacturer's press shop is shown in FIGURE 6.3. With the revised workstation and storage layout, and with the materials handling procedures systematized, the next stage in the implementation of the JIT Production system can be attempted; a setup time reduction programme.

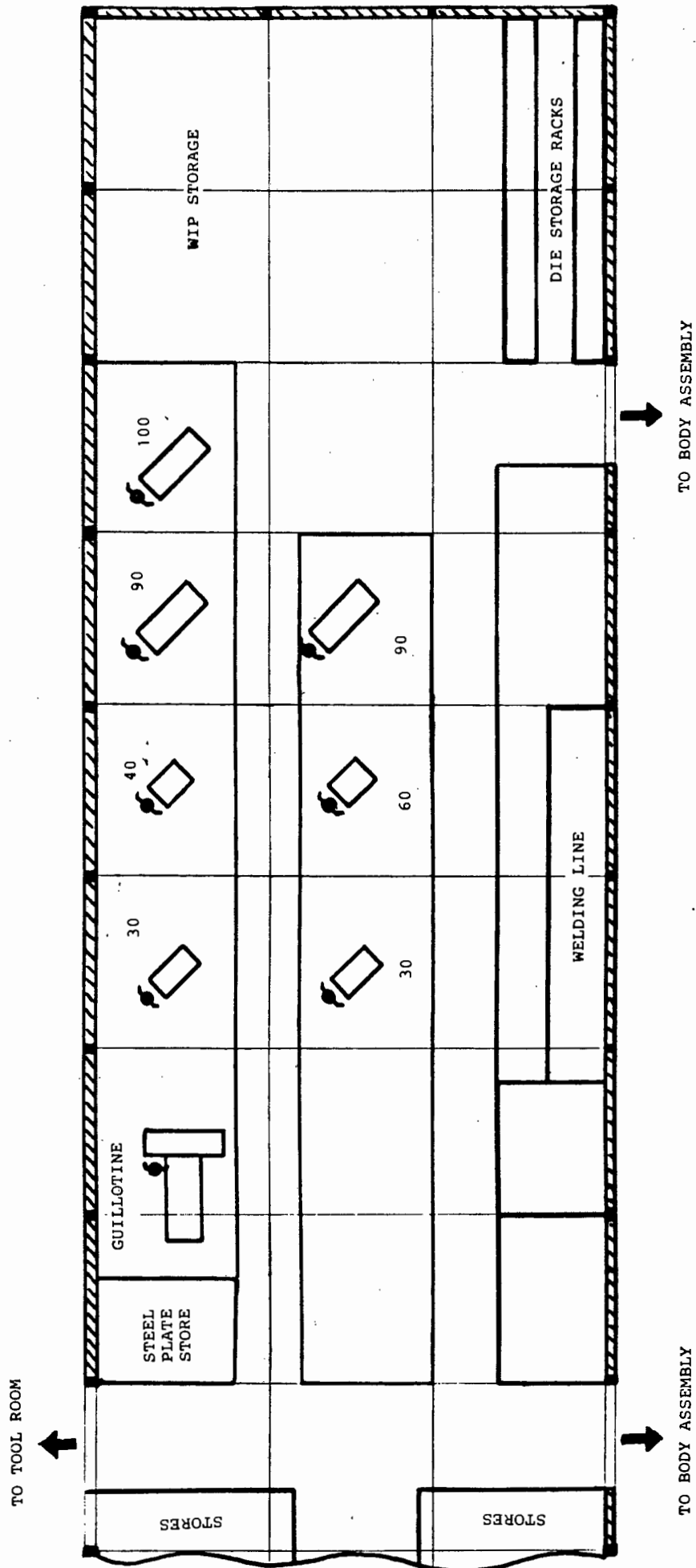


FIGURE 6.3 : Final Floor Layout for Press Shop

6.3 THE SETUP TIME REDUCTION PROGRAMME

The reduction of setup times is vitally important if the JIT requirement of small lot sizes and a flexible manufacturing plant is to be fulfilled. One cannot rely solely on a new layout to achieve plant flexibility. Therefore the importance of reduced setup times should be reflected in the amount of thought and planning that goes into the setup reduction programme.

A five stage implementation plan is recommended for the above task. This plan may be applied generally, and will only be found to vary in complexity depending on the size of the organization and the nature of the business. The plan is outlined below, and developed in further detail.

6.3.1 SETUP REDUCTION PLAN OUTLINE

1. Organization Stage

This first stage involves the selection of the people who will be directly concerned with the setup reduction programme. Setup reduction goals should also be decided upon.

2. Preparation Stage

Stage Two is the stage where those involved in the programme will be suitably trained and prepared for the task ahead.

3. Documentation Stage

Stage Three requires the identification and documentation of an average setup prior to commencing the actual setup reduction measures.

4. Analysis of Setup Stage

Stage Four requires the analysis of the setup procedure by the implementation teams, and the identification of any methods by which setup times may be reduced.

5. Implementation Stage

The final stage requires the improvements suggested in Stage Four to be implemented. Documentation of the new methods should be performed.

6.3.2 ORGANIZATION STAGE

The selection of suitable people to carry out the setup reduction programme is important if it is to have any degree of success. Such a task cannot be a one- or two-man show, although this does not mean that implementation teams should be too big either.

The choice of a suitable project leader should be the first task. Not only should this person be technically competent and analytically minded, but he or she must have the ability to lead people and manage and co-ordinate a project of this nature.

The balance of the team members should comprise the following: the area supervisor, some technical experts (who will be responsible for putting plans into action in the form of modifications to machinery, performing some design work, etc.), and some people taken from the shop floor. The latter are necessary for two reasons. First, they are the people with the most detailed knowledge of actual shop floor conditions, and thus are able to contribute accordingly. Second, without the active support of these people, the programme may not be as successful as anticipated due to a reluctance to change to the new methods. In smaller companies attempting a setup reduction programme, the setup reduction team members may even be the same as the JIT Production implementation teams.

The organization stage not only includes the selection of setup reduction team members, but also the choice of suitable equipment on which to perform the initial reductions and the formulation of initial setup reduction goals.

Equipment on which to perform the initial trial reductions will have been selected on the basis of the study performed in Chapter Five. For example, a machine which is causing a bottleneck, one which is not as flexible as it should be or one on which the setups are particularly complex. For the filter manufacturer, it was discovered that their 60 ton hydraulic press was the most heavily utilized and thus would probably provide the most opportunities for setup improvement.

First attempts at setup reduction should be limited to one, or at most two machines. Any more than this may only lead to confusion and a slower progression up the learning curve. With experience, reduction efforts can then be expanded to include a group of machines, or even a whole section of plant at a time.

Finally, in this first stage of setup reduction, it is important to formulate setup reduction goals. These are entirely arbitrary, but must be adhered to as closely as possible so that the programme does not lose momentum. For example, a 50% reduction in setup time in six months may be required by management.

Stage Two, the preparation stage, may now be attempted.

6.3.3 PREPARATION STAGE

Having selected a suitable implementation team, and formulated the setup reduction goals, team members should now be trained for the task ahead.

A training programme should be established, and a suitable time frame imposed on it. This programme should be led, if possible, by someone not actually on the implementation team. For example, the plant industrial engineer may assume the task.

The objective of this training period is to cover the ground rules of setup reduction. Further training, in the form of actual practice with setup reductions, will come later. The following aspects of setup reduction should be explained to the implementation team:

1. What the organization is actually trying to achieve with the programme.
2. Why it is necessary to decrease setup times (SECTION 3.1.1 describes the relationship between short setup times and plant flexibility).
3. Who is actually involved in the setup reduction task and what is expected from each person concerned.
4. How the setup reduction programme will be tackled.
5. Some specific techniques for setup reduction applicable to the work situation.

The training should, if possible, be so geared as to begin to stimulate further ideas for setup reduction apart from those mentioned in Point 5 above. This is where the correct choice of project leader is crucial. His or her enthusiasm for the task ahead will rub off on the team, and they will start to become more actively involved in the project.

6.3.4 DOCUMENTATION STAGE

The third stage in a setup reduction programme is to analyse an existing setup procedure for the machine or group of machines chosen in Stage One. The information thus obtained should be suitably documented, by the methods described later in this section.

A video recording of the existing setup procedure is an extremely effective method of capturing data, with the added advantage that it can be reviewed at leisure, or in a more appropriate environment. If such recording equipment is

unavailable, use will have to be made of two of the more traditional industrial engineering tools; a stopwatch and clipboard. It should not be forgotten at this point, that a machine setup is from when the equipment stops one operation to when it produces the first good part on the succeeding operation.

A chart, such as that shown in FIGURE 6.4 below, should be used to record on paper the setup procedure. Any problems that occur during setup, including those of quality problems associated with the first run, should also be recorded.

ELEMENT NUMBER	ELEMENT DESCRIPTION	ACTIVITY CODE	CUMULATIVE TIME	ELEMENT TIME
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				

FIGURE 6.4 : Documentation Chart for Setup Reduction

The activity code in Column 3 is useful for describing, at a glance, the nature of the activity, and for helping to identify the groups of elements that take up undue time during the setup process. Any suitable activity code may be used, but a suggested one is the following :

- ADJ - Adjustment. Therefore eliminate.
- EXT - External operation. Therefore eliminate.
- C - Cleaning operation.
- CL - Clamping or unclamping operation.
- M - Move operation. Eliminate or reduce if possible.
- P - Problem activity.

Other codes may be added if appropriate.

Once the setup procedure has been documented, the setup steps should be ranked in descending order of element times. This will help the implementation team to identify where the most significant time savings are to be made.

One caution, when compiling these lists, is to make them neither too detailed nor too brief. The first will only get the team confused with detail, and the second will not provide enough. The idea is to give an overview of the whole setup process, from which patterns will begin to emerge. For example, it may be seen that there is excess time spent purely on cleaning a tool bit, or on adjusting a press stroke.

6.3.5 ANALYSIS OF SETUP STAGE

Stage Four requires the analysis, by the implementation team, of the existing setup procedures , with a view to identifying where reductions may be made. The team should concentrate on four areas where downtimes due to setup may possibly be reduced.

1. Internal and external setups should be identified, and as much as possible of internal setup converted to external. Often, reduction targets may be attained purely from concentrating on

these aspects of the setup procedure.

2. Adjustments should ideally be eliminated, or reduced as much as possible. There may be tool adjustments which cannot be totally deleted, and so should be converted to external setup.

Adjustment problems fall into three categories, and are:

- Where the new job takes a short time to set up after the old one has been torn down, but where it takes a long time to adjust the machine to obtain a product of suitable quality.
 - Where multiple adjustments are required on a machine, such as a press, to position the die in exactly the right place. Ways of making the new die self-positioning should be sought after.
 - Where machines are infinitely adjustable over a given range. Those parts made on the machine should be determined, and only those adjustment positions required to make the part marked. Instructions showing which positions are required for each part should be developed.
3. The modification of clamping methods is another way of drastically reducing setup times. Most often, threads are used to clamp, and much time is wasted winding them up and down. There are however, a multitude of other devices which may be used with the same effect, and cost relatively little too. Pneumatic cylinders, latches and cams are just three examples. Any clamp, whatever its nature, only has to meet three requirements. It should be just adequate for the stress forces, it should complete the clamping procedure in one or two motions, and it should eliminate the need for tools.
 4. The fourth area in which downtimes may be reduced is to eliminate any problems which prevent trouble-free setup. Any problem not specifically outlined in 1, 2 or 3 above falls into this category.

6.3.6 IMPLEMENTATION STAGE

Stages One to Four set the scene for carrying out the actual setup reduction improvements, and it is in this final stage where the improvements are physically implemented.

Stage Five should only be carried out after the appropriate people have been notified of the changes to come. Included in the list of people may be supervisors, certain management staff, quality control personnel, or shop floor workers, depending on who is affected directly by the modifications. The modifications may then be performed. Not only this, but the documentation of the new setup methods must be compiled. This documentation will serve later as a comparison tool between the new and old methods.

The reduction of setups may, at a first attempt, involve purely the conversion of internal to external setup, as this can be done at no or little cost. The modification of setup methods by these means will require the various tool setters to change their habits. In fact, this also applies to decreasing setups by tool and equipment modification. The tool setters may, however, see no reason to change their way of performing the task, and will quickly lapse. Education and practice are the answers here. Education in the form of why the changes have been necessary (hopefully already carried out at this point), and practice to engrain the new methods. Supervisors must, especially in these initial stages, be constantly on the lookout for deviations and point them out immediately. With time, they will see that "working smarter, not harder" has definite advantages.

A setup reduction programme is not, nor should it be, a once-off effort. When the target for setup reduction has been attained for the machine or group of machines chosen, a new target should be set. This may again be on the same equipment, or on some other machine where a problem has come to light. The process is thus ongoing.

Another fundamental component of JIT is a preventive maintenance programme, the purpose of which is to enhance machine performance and increase machine availability. The establishment of such a programme is now described. The programme as outlined is intended to provide a general guidance, and its details will, of course, vary from manufacturer to manufacturer.

6.4 ESTABLISHING A PLANNED PREVENTIVE MAINTENANCE PROGRAMME

Prior to establishing a planned preventive maintenance programme in a plant, it is necessary to measure the effects of machine breakdowns or time presently spent on maintenance on overall production efficiency. The effects of this will ultimately translate as a cost.

There are a number of ways of measuring the "performance" of a machine. The formulae enabling this are outlined below. Not all the ratios need be used, but only those applicable to the actual work situation.

6.4.1 PRODUCTION PERFORMANCE MEASURES FOR MACHINERY

1. Availability of a Particular Machine:

$$\frac{\text{Production Operating Time}}{\text{Production Operating Time} + \text{Downtime}}$$

2. Mean Time Between Failures:

$$\frac{\text{Number of Operating Hours}}{\text{Number of Breakdowns}}$$

3. Mean Time to Repair:

$$\frac{\text{Sum of all repair Times}}{\text{Number of Breakdowns}}$$

4. Maintenance Costs in General:

$$\frac{\text{Maintenance Costs}}{\text{Maintenance Assets}}$$

Detailed maintenance costs can be analysed as follows:

- 4a.
$$\frac{\text{Maintenance Materials}}{\text{Value Added}}$$
- 4b.
$$\frac{\text{Maintenance Employee Costs}}{\text{Value Added}}$$
- 4c.
$$\frac{\text{Maintenance Work Sub-Contracted}}{\text{Value Added}}$$

5. Maintenance Ratios Related to Production:

$$\frac{\text{Total Direct Hours of Maintenance Labour}}{\text{Total Production Direct Hours}}$$

6. Department Maintenance Ratios;

$$\frac{\text{Total Cost of Maintenance}}{\text{Total Hours Worked}}$$

(gives a total maintenance cost per hour worked)

$$\frac{\text{Maintenance Hours on Preventive Maintenance}}{\text{Total Maintenance Hours}}$$

$$\frac{\text{Maintenance Hours on Emergency Maintenance}}{\text{Total Maintenance Hours}}$$

$$\frac{\text{Maintenance Hours on Corrective Maintenance}}{\text{Total Maintenance Hours}}$$

7. Maintenance Materials Management:

$$\frac{\text{Cost of Maintenance Materials Used}}{\text{Maintenance Inventory Value}}$$

(equivalent of a stock turn ratio)

8. Volume of Work:

$$\frac{\text{Total Hours of Maintenance Work Produced}}{\text{Total Maintenance Clocked Hours}}$$

(provides an indication of efficiency)

$$\frac{\text{Number of Maintenance Work Orders on Hand}}{\text{Number of Maintenance Work Orders Completed}}$$

in a Given Period

6.4.2 ESTABLISHING THE PROGRAMME

With an idea of the performance of the various machines in the work area, it is now possible to commence the programme. A number of steps should be followed, which are outlined below.

1. Make a list of all items that need maintaining. Included should be not only process equipment, but safety equipment, transportation equipment, jigs and so on. The list should provide details of equipment locations, a brief description, whether the machine is a critical one in the process or not, etc.
2. Produce a schedule, for each piece of equipment, of any maintenance work necessary and its frequency. The schedule must be based on such alternatives as replacing an item only when failure has occurred, replacing when equipment no longer reaches acceptable quality standards, replace after a certain number of operating hours, replace after a certain period of time etc.
3. List all mandatory work.
4. List all routine inspection requirements.
5. List all work deemed desirable by the appropriate production manager. Estimate the frequency of such work.
6. Prepare standard instructions in detail, along with tool and material requirements.

7. Develop time standards.
8. Establish a programme of planned maintenance work, with each task being allocated a certain period of time. The schedule should be agreed upon and adhered to. Reviews from time to time may reveal parts of the programme which are unnecessary or whose frequency can be reduced.
9. Prepare a plan of work on a running basis over at least twelve months. Allow a capacity for unplanned work.
10. Issue work through a central control point, and obtain record data on completed work before handing out new.
11. Continually verify times, costs, etc., to provide updated data for future planning.
12. Ensure plant and equipment register is kept up to date.

CHAPTER SEVEN
THE DIFFICULTIES OF IMPLEMENTING JIT IN A
SMALL MANUFACTURING ENVIRONMENT : A SUMMARY

The objective of these last few chapters has been to attempt to identify those aspects of JIT Production which are the more difficult for the small to medium sized manufacturer to apply.

The assessment and redesign of the press shop, based on JIT methodologies, tended to emphasize many potential JIT implementation problems which would be applicable to any manufacturer going this route. However, certain implementation problems that may be unique to the small manufacturing environment were discovered, and are summarized in the sections following. It should be remembered that specific problems will vary from factory to factory, and it is only once a programme has been initiated, that those problems peculiar to the organization will begin to surface.

7.1 ASSESSMENT AND PLANNING FOR JIT

Although Spurgeon stated that JIT should not be thought of as a project to be planned and completed, but more of a concept to be applied, this does not release the manufacturer from the task of planning altogether.

The experiences of the filter manufacturer tended to confirm the importance of the planning task. An absence of a long-term implementation plan, with no overall goal, meant that the initial success of the JIT effort had been limited. Employees therefore lacked a unified vision as to what the programme was trying to achieve, and even within management circles there was conflict as to what was ultimately important.

An adequate assessment of existing production using simple work study techniques, and prior to the implementation of JIT, also emerged as a factor of great importance. Without this assessment, it would be difficult to observe the effects of any changes, and whether these changes were beneficial or not.

Smaller manufacturing firms may tend to find it more difficult to adequately perform these assessments, and to plan properly for the introduction of JIT. Primarily, the problem may be one of a shortage of manpower. In a rapidly expanding small business, this may even be accentuated. People, already overworked, suddenly have to make time for these new planning activities, with the result that they are not done properly. For a fully operational JIT system to get going in the shortest possible time, the significance of these tasks should not be underestimated.

7.2 TRAINING FOR JIT AND THE FORMATION OF IMPLEMENTATION TEAMS

Inadequate training, along with insufficient planning, also emerged as one of the greatest hinderances to the successful implementation of JIT. It is impossible for people to perform if they do not know what is expected of them. Therefore adequate thought and time should be given to this task.

The experience of the filter manufacturer confirmed this fact. When JIT Production was initially attempted, people had not been suitably prepared, and thus had not grasped precisely the implication of these new techniques. JIT had not met with the initial degree of success that it should have.

One of the difficulties inherent in this area of training seems to be one of manpower, particularly in a small manufacturing company whose resources are limited. Adequate training requires time to be set aside for the preparation of operating and training manuals, for scheduled training and feed-back sessions, or for suitable "practical" workshop sessions. This is time that often is not readily available, and yet must be made so.

The actual implementation of JIT cannot be carried out by one man, who simply dictates new methods and procedures. Conversion to JIT is very much a team effort, with implementation teams assuming a key role in the process. These teams should be put together carefully, and with the correct leadership.

7.3 REVISION TO THE PHYSICAL ASPECTS OF PRODUCTION

True JIT will impact on many factors of production. For example, the revision to plant layout will require attention to be given to materials handling procedures, tool storage methods, and the storage of work in progress.

The revision to these aspects of production when preparing for the introduction of JIT is independent of the size of the manufacturing firm. Suitable attention must be given to all these factors if the various forms of manufacturing waste are to be reduced, and attention must not be concentrated on just one or two of them, eg materials handling. Individual benefits will of course arise from doing this, but as and when the plant is converted to a pull system, other shortcomings to be found in the system will become apparent. Even if a fully operational pull system is not installed, benefits will then already have been obtained. These revisions must be done and refinements made to them before installing the pull system.

7.4 PREVENTIVE MAINTENANCE

A preventive maintenance programme will be necessary for both large and small manufacturing organizations wishing to convert to JIT.

The difficulties of setting up such a programme in a small manufacturing plant may be greater than in a large plant. A small in-house maintenance department will mean less resources, both of capital and personnel. In larger companies with a well developed maintenance department, this problem will not be so acute.

The other problem that may arise in establishing a preventive maintenance programme may be in convincing management that such a move is actually necessary. They may see no reason to shut down machinery from which more capacity is required. The extent of the maintenance will vary with the machinery involved, as some will be more prone to failure than other. In

this case, it will be easier to convince management that a preventive maintenance programme is needed.

7.5 REDUCED SETUP TIMES

The reduction of machine setup times is an exercise just as well performed by the small as the large manufacturer. One of the restrictions the small manufacturer may face is a limited budget for the task. Even then, large reductions in setup times are possible with almost no capital outlay.

A setup reduction programme aids in the task of concentrating setup reduction efforts the important aspects of a setup reduction programme.

7.6 OTHER FACTORS LIMITING THE SUCCESS OF JIT

There are a number of other techniques which may be more difficult for the small manufacturer to apply and which may limit the success of his JIT effort.

One of these is the co-operation with suppliers for the Just-In-Time delivery of purchased parts. A small manufacturer will generally consume less of a product than his larger counterpart, and consequently the supplier may be less willing to enter into such an arrangement. If the supplier can be convinced that he will be the only supplier, arranging such a deal may be easier. It should be remembered, though, that such mutually beneficial deals should only be arranged as and when the manufacturer's own in-house pull system is functioning correctly.

The introduction of Quality Circles may or may not be easier for the larger manufacturer to instigate. Even if this approach is not used, improvements to the quality of a company's product is within reach of all, and the size of a company should not be seen as a limiting factor.

Finally, the success of a JIT effort will be reduced if a pull system is prematurely introduced ie. before physical production

problems are identified and eliminated. If production is unable to support the use of Kanbans, the very problems the Kanbans are trying to reduce, such as work in progress and long lead times, may become more acute. Consequently, efforts will be set back, and it will take longer to get the plant fully functional under a pull system.

There is nothing complicated behind the concept of JIT Production. The heart of it is simply one of the reduction or elimination of all forms of manufacturing waste. The achievement of this goal will have tremendous benefits, for both small and large manufacturer alike. It is once this has been done that a plant may convert to a pull system and achieve true Just-In-Time or Stockless Production. Basic workstudy analysis, along with common sense, seem to be the best approaches to waste elimination, and is a task that everyone in the factory may become involved in.

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CHAPTER EIGHT
RECOMMENDATIONS

In the light of the insights obtained from the research, the author would like to make a number of recommendations to the small manufacturer wishing to establish Just-In-Time Production in his manufacturing facility.

1. Study in as much detail as possible the concepts behind JIT. This applies to all personnel in a factory. Management should have enough understanding to guide the rest of the factory through any confusion caused by the change. Training programmes should be initiated for the education of both supervisor and shop floor worker.
2. Establish clearly defined goals and objectives for the JIT programme. Inform all key people exactly what is required of them, and the nature of their contribution to the overall programme.
3. Select suitable JIT implementation teams, and thoroughly prepare them for the task ahead. Make known to the members their specific rôles, and how they will be contributing to the long-term goals of the company.
4. Select a suitable pilot project with which to initiate the programme. The project may focus on a department, a group of machines, or a production line. The criteria for its selection is that it should be representative of the type of problem to be found in the rest of the plant, and that it is small enough to highlight potential implementation problems.
5. For the pilot project, analyse thoroughly, using workstudy techniques, the production situation existing prior to any changes being made. This will pinpoint potential bottlenecks and problem areas, and form a basis with which to begin improvement efforts. It will serve too as a comparison between old and new.

6. Carry out the necessary physical changes, eg. plant layout, to the plant to correct any abnormalities determined as above. The implementation teams should be involved in this and the previous stage.
7. Establish a preventive maintenance and setup time reduction programme. Work to reduce defects and increase product quality.
8. Implement the pull system. Do this as quickly as possible, so as not to have a mixture of pull and push systems in place for too long.
9. Once confidence has been gained with the pilot project, extend the programme to the remainder of the factory. Continually strive to iron out any difficulties and problems that surface. Work at reducing inventory and work in progress levels.
10. Extend the pull system to suppliers, by arranging mutually beneficial deals.

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APPENDIX A : THE SINGLE MINUTE EXCHANGE OF DIES (SMED) SYSTEM

The basic concept behind the SMED system is that any machine setup can be separated into two fundamental components - internal setup and external setup (termed IED and OED respectively). IED involves those operations which can only be performed when a machine is stopped, whilst any OED operations can be conducted with the machine still running.

In order to decrease setup times, a number of stages of development have to be followed. These stages are shown in FIGURE A.1 below.

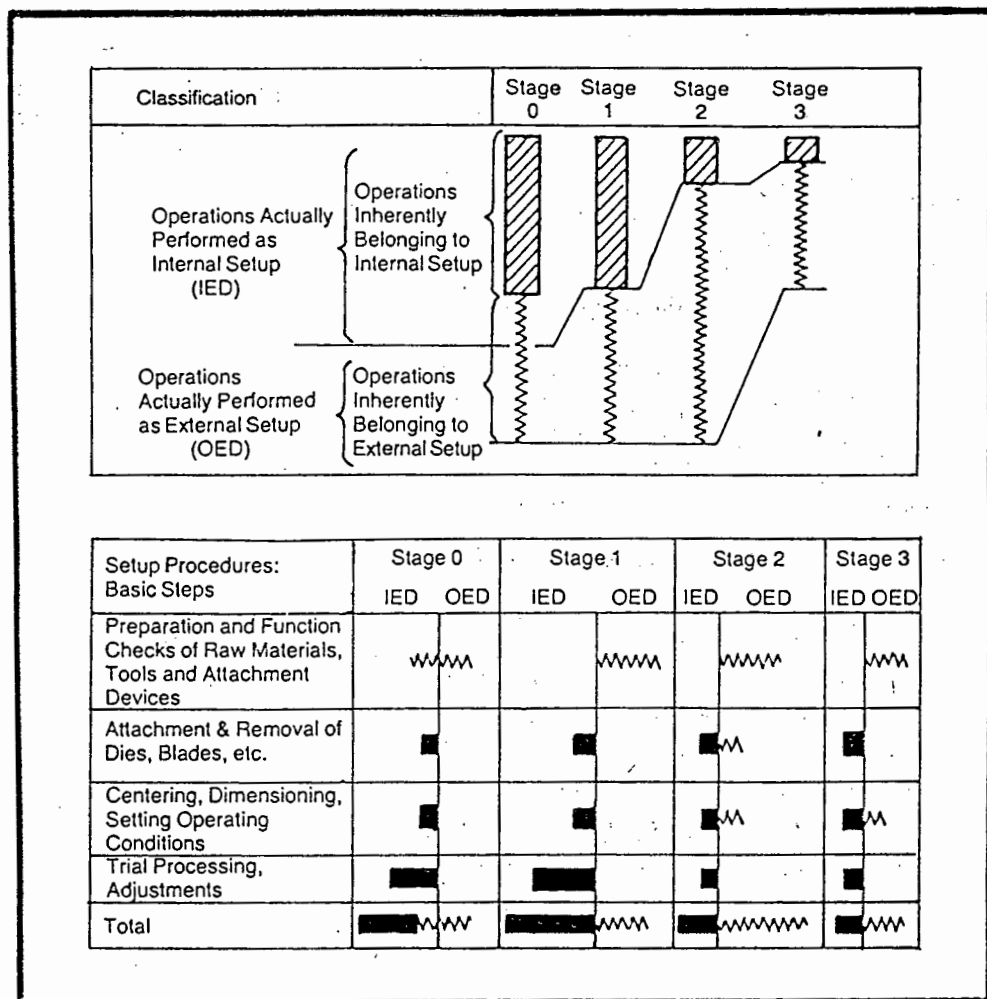


FIGURE A.1 : Conceptual Stages for Setup Improvement

In the preliminary stage, designated as Stage 0 in the figure, internal and external setups are confused. This is fairly typical of traditional setups, where what could be done externally is done internally, and machines remain idle for longer than necessary. Actual shop floor conditions should be studied when planning for SMED, to see how setups are presently performed, and there are a number of techniques for doing this.

1. Analyze the production with a stopwatch, to see how long the various operations in setup take.
2. Interview floor workers to find out, as near as is possible, actual conditions.
3. Use, if possible, videotape to provide a record of the actual shop floor setup operations. A study of the existing situation will help to generate ideas for further improvement.

With this data, Stage 1 can be attempted. This stage involves the distinguishing between internal and external setup. A checklist of all the parts and setup operations required will enable this to be done more easily. It is possible, by simply distinguishing between IED and OED, and treating as much of the setup operation as possible as external, to reduce machine downtime by 30-50% (Shingo [31] p29).

Stage 2 involves the conversion of internal to external setup. Operations should be re-examined to see whether any have been wrongly assumed internal. methods of converting internal to external setup should be thought out and tested.

The last stage, Stage 3, requires the streamlining of operations, the further reduction of setup times (both internal and external), and even the elimination of some operations.

Stages 2 and 3 do not necessarily need to be performed sequentially and in fact are often done concurrently.

APPENDIX B : JIT AND SMALL LOT SIZES

By manufacturing only at the market rate of demand, inventory is not produced. This is due to production being exactly equivalent to demand. The ideal in such a situation is that if only one part is required, only one part must be manufactured, and so one becomes the ideal lot size.

The ability to produce such small lots means that one must have an extremely flexible manufacturing plant which enables customer requirements to be fulfilled and nothing more. However, with conventional thinking, this lot size of one is difficult to believe possible, as it has traditionally been assumed that large lots are necessarily better. Large lots mean, though, that production has not been mastered to the extent that only one part can economically be produced if that is all that is required. A comparison between production with large lots and that involving small lots is presented.

Traditional Manufacturing Strategies and Large Lot Sizes

Setups traditionally have involved a great deal of time, and the "solution" to this problem has been to increase the lot size. The setup time, and thus the costs associated with it, are distributed over a wider number of units, and become slight when compared with the total batch processing time. Low volume orders on the other hand, present a different picture. The proportion of setup time to processing time increases for each unit or batch, and so lot sizes are often increased to counteract these effects by combining several orders (such as manufacturing for anticipated demand inventory). The excess inventory which results from such actions is wasteful. Wasteful in that it requires storage space, extra handling, does not produce added value, can deteriorate over time, and increases lead times. All of these cost money.

An ideal lot size, termed the Economic Lot Size, has been arrived at. FIGURE B.1 represents the relationship between lot size and inventory and setup costs.

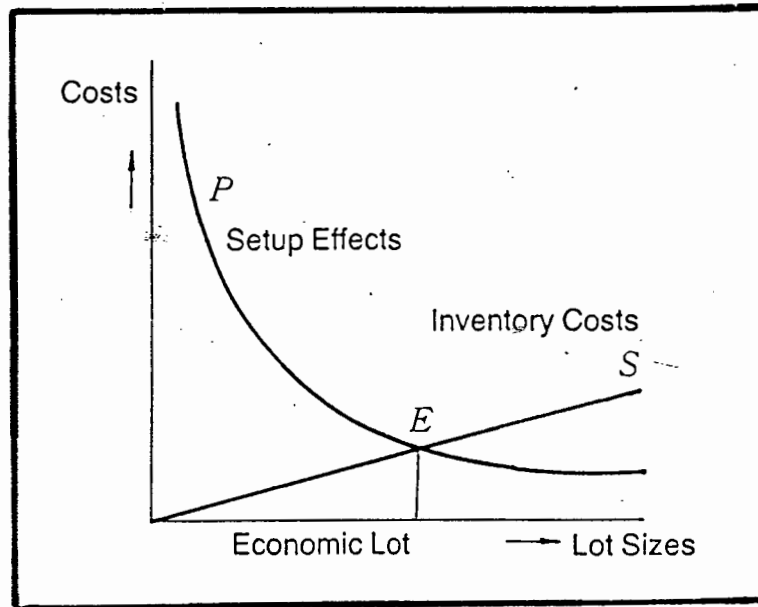


FIGURE B.1 : The Economic Lot Size

A Shortcoming in the Economic Lot Size

Although correct in theory, the adoption of the Economic Lot Size makes the false assumption that drastic reductions in setup times, and thus setup costs, are impossible. If a long setup of traditionally a few hours were reduced to a few minutes (not an impossible goal as already explained in APPENDIX A), then even without increasing lot size, the ratio of setup hours to processing hours would become extremely small. It would thus become unnecessary to compensate for the effects of long setups by producing large lots, and customer requirements can be satisfied without the added waste from excess inventory.

APPENDIX C : EXCESS INVENTORY AND CAPITAL INVESTMENT

The objective of any business is to make money. This money does not necessarily translate as profits, as is the common interpretation, because these profits may not accurately reflect the well-being of the organization. For example, it might be that some companies never show a profit, or perhaps only a small one, and yet are extremely successful in practice.

One of the uses of profits, though, is as a tool for maximizing the net cash flow of a company. It is in being able to increase this cash flow that employees, dividends, vendors and so on are able to be paid. Likewise, the reduction of inventory is another means of increasing this flow.

An example may help to clarify the point. Harrison gives the following case of a typical American electronics firm.

Sales Revenues	\$100 Mil.
Cost of Sales	\$ 80 Mil.
	—————
Gross Profits	\$ 20 Mil.
Taxes	\$ 10 Mil.
	—————
Net Profit	\$ 10 Mil.

Average Inventory @ 3 Turns/Year = \$ 27 Mil.

As can be seen, the average amount of money tied up in inventory is equivalent to 2,7 years worth of profit. Even if the firm were to double its profits in any one year, less cash would be generated than a 50% reduction in inventory. This reduction in inventory, with a corresponding increase in cash flow, is one of the major tasks facing those wanting to establish a successful JIT system.

Techniques for Reducing Inventory

There are many techniques and opportunities for reducing inventory. One such opportunity is the disposal of inactive inventory. Inactive inventory consists of material which is currently in the books, but for which there is no reasonable expectation of demand. The identification of the inactive inventory may be difficult to do in practice, as no matter how well a data base has been kept up to date, it will seldom prove to be accurate. Inventory which is thought to be inactive may be the opposite, and so a list of all such material should be issued prior to disposal (either scrapping or to a buyer) to anyone who may possibly have a need for it.

An overloaded master schedule is another cause of excess inventory. Such a schedule demands more material than the company can utilize, with the result that inventory builds up either on the shop floor (in the form of excess WIP) or in stores. Adherence to realistic schedules is the answer here; a task easier said than done.

The reduction of lead times has already been discussed in Chapter 3, and it is by doing this that excess inventory may be reduced. Finally, there is what is known as the MORE approach to less inventory. This approach combines aspects of both Management By Objectives and of quality circles. The MORE approach is outlined as follows:

- make a valid MEASUREMENT of some productivity parameter. In this case the amount of inventory.
- agree upon an OBJECTIVE, and graphically display it in a prominent position.
- continuously provide RECOGNITION for results.
- EDUCATE employees on an on-going basis to provide them with the necessary skills to make improvements.

APPENDIX D : CALCULATION OF THE NUMBER OF KANBANS REQUIRED IN A DUAL CARD PULL SYSTEM

Since most parts will be moved in batches in standard containers, the number of cards issued will represent the total number of containers that should be in the system for each part. The formula given is an overall estimation formula, which covers a variety of situations.

$$y = \frac{D(T_w + T_p)(1 + X)}{a} \quad (D.1)$$

Where:

y = Number of cards (move + production)

D = Planned rate of use per day (derived from the final assembly schedule by exploding it as summarised into a daily master production schedule.

T_w = Waiting time, or move card cycle time (the amount of time for one move card to make one complete circuit between the source point of the part and the use point of the part.

T_p = The processing time necessary for a production card to make a complete cycle through the work centre producing the part. (Includes time for setup, running, inspections, material preparation, and the extra time necessary for the work centre to maintain a balanced running operation.)

a = The number of units of the part placed in each standard container.

X = An allowance for an extra time (cards) because of inefficiency.

Once the number of parts per container has been decided, working with the number of containers per day may be more convenient. The formula can thus be decomposed as:

$$y = \frac{(D)(T_w + T_p).(1 + X)}{(a)} \quad (D.2)$$

(D) = number of containers per day. At least 10 are required for (a) flexible transport and production.

To calculate separately how many move cards and how many production cards are needed, decompose D.1 as follows:

$$y = \frac{(D)T_w(1 + X_w)}{(a)} + \frac{(D)T_p(1 + X_p)}{(a)} \quad (D.3)$$

[move cards] [production cards]

Note:

- The number of move cards needed includes an allowance for inefficiency. This inefficiency allowance should be kept to 10% or less, to prevent work centres from transmitting too much variance.
- Determining the inefficiency allowance for the number of production cards is difficult, so no figure is given.

The overall inefficiency allowance $(1 + X)$ is defined as:

$$\frac{\text{Sum of all move cards allowed} + \text{Sum of all production cards allowed}}{\text{Sum of all cards allowed if no inefficiency}}$$

APPENDIX E : PRESS SHOP MACHINE UTILIZATION SPREADSHEET PROGRAM

The Lotus 1-2-3 Spreadsheet program enabled an analysis to be made, with a visual presentation in graph form, of the utilisation of the various presses in the press shop. This analysis was important as it permitted the determination of bottleneck areas in the workshop, and provided a basis for redesigning the facility based on JIT ideas and techniques.

Program Structure

Results are presented, and display the following information for each press:

- % of available time the machine is actually being used.
- % of available time the machine is unavailable due to undergoing repairs or maintenance.
- % of available time spent on setting up the machine for the various operations.
- % of available time the machine is not being used.

Available time is defined as the number of hours in any one particular month (including second shift).

Standard times (for operations or setups) are taken from available information.

Results are based on making only enough components to satisfy that months sales, and not for stock.

The program is structured as follows:

SECTION 1 : Input of Data

Input of the following data at the beginning:

- month and year.
- sales figures per finished unit for that month.
- downtimes for each machine due to maintenance/breakdown.
- public holidays in days.
- second shift days.

SECTION 2 : Bill of Materials

For each finished unit sold, the bill of materials for the pressed parts os broken down as follows:

PART NO	DESCRIPTION	USEDON	NO.OFF	MONTH VOL.
				monthly sales x no.off

SECTION 3 : Total Volumes per Part per Month

This section details the total number of each pressed part required to satisfy that month's sales. It is broken down as follows;

PART NO	DESCRIPTION	MONTHLY VOLUME
		monthly volumes for that part (from Sect.2)

SECTION 4 : Machine Setup Details

Section 4 calculates the average number of setups that are performed in any one month to fabricate a particular component. Lot sizes are made up of multiples of a full 1225 x 2450mm sheet of steel, and the average number of sheets processed as one lot was obtained from the shop floor supervisor:

PART NO	DESCRIPT	MONTHLY VOL.	SETUPS PER MONTH	LOT SIZE	SHEETS PER RUN	PARTS PER SHEET
		input from Sect 3	monthly vol/lot size = setups per month	parts per sht x sht per run = lot size	avg no sheets procesd at time for part	no of comp. from each sheet

SECTION 5 : Machine Standard Processing Times

Section 5 calculates the total time for the month, that each machine is occupied in actually producing the number of parts required (calculated in Sect.3). For each machine, processing times are added to arrive at a total monthly processing time. The processing of certain parts could be done on more than one press. Where this was the case, half the processing time was allocated to one machine and half to the other, in order to calculate the average processing time for any one machine. Calculations are performed as follows:

PART NO	DESCRIPT	MACHINE	
		STANDARD TIME	STD TIME x MONTHLY VOL
		taken from data	gives time reqd. for month to produce reqd. no. of parts on any one machine
			Σ = total time to prod all parts for that month

SECTION 6 : Machine Standard Setup Times

This section calculates the total time occupied for the month in setting up the machines for production. For each machine, the setup times for the various operations are added to arrive at a total setup time figure. Calculations are performed as follows:

PART NO	DESCRIPT	MACHINE	
		SETUP TIME taken from data	SETUP TIME x SETUPS/MONTH gives no. of hours spent setting up per month to produce reqd. parts on a particular machine Σ = total time spent setting up in any one month

SECTION 7 : Calculation of Machine Utilization

Machine efficiencies are calculated in Section 7, and are worked out as:

Monthly Hours Available = X hours

Operating Efficiency % = (processing time)/X x 100

Downtime % = (downtime)/X x 100

Setup % = (setup time)/X x 100

Waiting % = 100 - (% eff) - (% down) - (% setup)

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