

/ACHIEVEMENT OF EFFICIENT OPERATIONS CONTROL  
THROUGH JUST IN TIME PRODUCTION MANAGEMENT/

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A MASTER'S REPORT

submitted in partial fulfillment of the  
requirements for the degree

MASTER OF SCIENCE

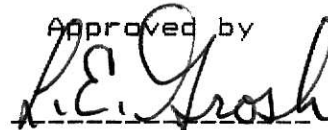
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## INTRODUCTION

Production control systems play an important role in the pursuit of the manufacturing objective. This objective is to provide maximum customer service through efficient plant operations, while maintaining a minimum inventory investment in manufacturing plants. In the history of manufacturing, there is a progressive improvement of these control systems for solving the problems in production management. These problems arise due to the diversification of the manufacturing process and the variability in the demand. The large number of components and stages of manufacturing with the high variability of production yield intensify this problem further. Growth and enhancement of system performance is inevitable as these problems remain.

To achieve a better control over the diversity of manufacturing operations, different production schemes have been tried. Some of the more successful of these have been job shop, flow shop and others that support repetitive manufacturing. In a repetitive manufacturing environment, a high volume of discrete parts or assemblies are manufactured using a consistent and a continuous process with a major percentage of the product's value being contributed by raw material. The recent manufacturing advances such as Group Technology (production of similar components and related assemblies in a U shaped cell capable of processing the component in a predetermined manner), Flexible Manufacturing System (production of similar components and

related assemblies in a transfer line configuration of machines capable of processing the components through software control), and cellular manufacturing schemes have provided the capability of producing very small lots of a diversified product variety. Today computers do serve as an overall planning tool and aid in the monitoring of material flow, yet, even with the best of the software it cannot prevent manufacturing from excessive WIP (work in process inventory), long lead times and queues, yield problems and other deficiencies of shop-floor operation. A few of the major problems are itemized below:

- i) Components arrive before/after planned scheduled dates.
- ii) Materials take up valuable floor space.
- iii) Units invariably find their way into unscheduled jobs.
- iv) Capital invested in dead inventory.
- v) Possible duplication of orders.
- vi) Inefficient quality control.

Though these have been mentioned, additional deficiencies in plant operations management can be added to the list, depending on the nature and type of a particular manufacturing industry.

The key to the success of a manufacturing system lies in the execution of the system. This success depends on the collection of correct data, presentation of accurate, reliable and timely information to management and accurate computation based on the information presented. Replacing the existing system with another without correcting execution errors will not generate improved results. In fact, a higher sophistication of the system leads to

more failure susceptibility through sloppy execution. Some commonsense techniques of plant control will provide more insight into production control than the incorporation of sophisticated algorithmic systems and software. Instead of designing production control systems for a complex manufacturing environment, the simplification of the manufacturing operation itself will minimize the problems of production control.

The point is not to blame the MRP (Manufacturing Resource Planning) based production control systems. In fact MRP has provided very valuable insights and has revolutionized the approach to the production control problem and has offered the capability to either slow down the job (de-expedite) or free up the production capacity for other jobs by expediting the process flow. That means, if a bottleneck occurs, it is possible for management to physically locate all other production orders for the affected end item and to change the operational due dates to some future period. Also, it provides an ability to foresee future demand on common components from other end items. It has been succesful in job shop manufacturing environments.

Today, even though the implementation of MRP systems in a variety of industries has resulted in an astronomical success, most of these industries are chasing an objective of improved financial information and network, distributed planning and quality improvement. About 50% of class A MRP users are working on the improvement of MRP activities to contribute to their Just-In-Time projects.

JIT projects are being launched in most of the better known industrial firms in the world. Richard Schonberger (Article viii) (U. of Nebraska) feels that tens of thousands of plants (besides those in Japan) now have JIT efforts under way, including most of the largest North American corporations. In a few companies, results are on five to ten fold reductions in lead time (thorough-put time). JIT has other names such as 'Zero Inventories', 'Material as needed' and 'Continuous flow manufacturing'. By replacing complexity with simplicity in manufacturing management, it has achieved reduced inventories of stock, raised flexibility in operations and enhanced quality of product. This has been achieved by its emphasis on cellular layouts in support of flow shop production.

This project aims at the study of JIT scheme and MRP systems. We attempt to integrate the JIT approach into the MRP plan so that the problems in production operations can be at least circumvented, if not totally avoided. An approach towards implementing JIT will be developed. The analysis to this problem begins with a study of inventory control and the side effects so generated due to high inventories in stock. The next section compares the MRP's response with JIT's solution to rising inventories and its shortfalls. The next section discusses the JIT system from definition to implementation. Causes or reasons of inadequacy will be sought through discussion of implementation criteria. The last section deals with pointers towards implementing and incorporating a JIT system either as a total

system or as a supportive system to MRP control. A summary concludes the project.

## THE PROBLEMS WITH STOCK INVENTORIES

Planning and control of production operations require the planning of production rates that meet demand requirements and attempt to minimize the costs associated with carrying of inventory and changes in the production rate. The building up of inventory results in inventory carrying costs which include the cost of storage, insurance and taxes and the cover up costs of risk associated with possible deterioration and obsolescence. On the other hand, the cost of changing the production rate is associated with hiring and laying off employees, or increase in labor capacity or changing equipment capacities.

The management of inventory is often the keystone to success in a manufacturing firm. The availability of right items at the right time supports the organizational objectives of profit, productivity, and return on investment. The absence of the appropriate inventory will halt the production process and will result in high investment, high inventory costs, low productivity, high production costs and poor customer service. Coordination at all stages of inventory management is required, as marketing needs finished goods to supply customers, manufacturing needs raw materials and purchased parts to produce finished goods, and the work in process affects production efficiency.

Basic inventory reduction offers the greatest potential for productivity improvement in industrial operations. The next



section elaborates on basic concepts and causes for systematic inventory reduction, and discusses the problems associated with large inventories.

#### CONCEPT OF INVENTORY REDUCTION:

The separation of income statements from balance sheets and the emphasis on profits has been followed by the American management tradition. This tradition encourages a philosophy of making profits and not making money.

Profits are the basis for corporate taxes. It is, therefore, always in the best interests of the company to increase cash flow. The real, ultimate objective is to maximize cash flow as cash is required to exchange material.

The following example demonstrates the effect of reducing inventory, with a direct influence on cash flow. Taking an example of a typical American electronics firm that turns its inventory about three times per year :

Sales Revenue	\$ 100 million
Sales Cost	80 "
Gross Profit	20 "
Taxes	10 "
Net Profit	10 "

$$\text{Average ITR} = 3 = 80 / (\text{Avg. Inventory Cost})$$

$$\text{Average inventory cost} = 27 \text{ million !!!!}$$

Putting in equivalence,

Average inventory cost	= 2.7 years of profits
50% Inventory reduction	= 13.5 mil cash + 10 mil profit
	= 23.5 mil cash
doubling profit	= 20 mil cash

So doubling the profit for one full year does not generate as much cash as 50% reduction of inventory. A 20% reduction equals to 5.4 million cash. This is as much cash as that could be achieved by six months operation or the equivalent profit for one half year.

The problems associated with large inventories are discussed.

#### EXCESSIVE LEAD TIME:

Traditionally, lot sizes are generally determined by applying the EOQ model,

$$Q = (2SR/Ck)^{1/2}$$

where,

Q = Economic Lot Size

S = Set up cost/lot

R = Annual Requirements.

C = Carrying cost

k = Constant associated with carrying cost expression.

Lengthy set ups for attachments such as dies, fixtures, and clamping systems necessitate large lot sizes due to the incurment of high costs and time. Actually we would not know that we are accumulating large inventories but this fact becomes clear

whenever we determine the average inventory turnover ratio. Reducing set-up times allows manufacturing in small lots and consequently lowers costs and increases flexibility in production.

Total machine set up usually includes the following tasks:

1. Assembly of tools.
2. Removal and storage of current tooling and fixtures.
3. Installation of new tooling and fixtures.
4. Adjusting of attachments for proper performance.
5. Testing.
6. Inspection.
7. Trial runs.

These tasks may be performed while the machine is still running (external set up) or while the machine is down (internal set up). Each individual task must be considered while attempting to reduce the total set-up time. Every phase of the entire activity at each work-center must be examined and any redundant motions, moves, and operations must be sought out for elimination.

If the machine is a computer controlled work center even its software needs to be evaluated critically, as it has been the author's experience that excessive operation time is utilized in non productive activities such as tool/turret indexing and dusting off of unwanted chips. The software should be so designed that the tool moves only in required paths on part geometry with no unwarranted repetition of its movement on the same path

already traced out.

In scheming out a proposed set up sequence, attention must be paid to the overlapping of multiple activities during the same time span. Such an activity would be the performing a change procedure or as much of it as possible when the machine is running (external set up) . This requires all attachments, tools and workers to be waiting when the machine stops. Immediately after use, attachments and tools need to be cleaned and prepared for next set up.

Enhanced operation efficiency will be gained by :

- 1) Reducing set up either independently or through a combination of design, trained procedure & improved tooling.
- 2) Implementation of clamp-on systems rather than bolt on systems.
- 3) Rather than assign independent set-up crews have operators do their own set ups where possible.

#### QUALITY CONTROL PROBLEM:

Excessive inventory acts as a 'safety valve' and covers this problem by excessive production to take care of scrap. This in fact, has a subsequent influence on the delay of the production schedule. If the manufacturing process involves a multiple number of stages in succession, and if at one of the stages, a 'bug' is introduced into the product then at the subsequent stages an unwarranted product value is added without

enhancing its capability. With a stricter inventory control, quality needs utmost emphasis as scrap and rework are required to be minimized. Any product that is made, should be made right the very first time.

#### CRITERIA OF OPERATIONS FLEXIBILITY:

Reduction of stock inventories is a commitment towards achieving a high turnover objective. High turnover means greater flexibility. High turnovers require a flexible operation capable of absorbing changes in sales forecasts, engineering design, product mix, and production rates. High turnovers do not necessarily mean dedicated equipment, as dedicating is normally an inflexible approach. Nor do high turnovers necessarily lead to flexible manufacturing systems which typically require an extensive capital investment and an elaborate floor layout. Instead, flexibility can be developed within an organization through the reduction of setup and the application of Group Technology on existing equipment and statistical process control application.

#### STORAGE VS. MATERIAL HANDLING :

In addition, two very considerable side effects are noted with excessive inventories--overflowing temporary storage space and unrequired material handling around large stacks of WIP inventories. The available space on the workfloor is taken up by the WIP inventories.

Space limitation is a problem when trying to upgrade the

production efficiency by the installation of superior material handling systems. Indirect labor cost is high as material cannot be moved directly and has to be passed around. In addition, the direct labor cost is high as the worker has to exert more effort to reach to a unit of stock.

Further complications such as the following are inevitable:

1. Systematic classification and coding of part numbers goes out of control. That means, a part might be associated with multiple part numbers or, a part number may identify multiple parts.
2. Materials get picked for unscheduled jobs.

Etc...

All these cited problems and complications prevent achieving operations control and they can be removed only by making an effort towards reducing the inventory. When the inventory is reduced, these problems are visible and then they can be solved with a coordinated effort.

#### INVENTORY REDUCTION:

Setting inventory reduction targets is an excellent means of producing results in a production environment. There is no standardized procedure for the evaluation of standing inventory. Spending time and effort on determining the correct level of inventory is, at best a poor use of resources. Too often a target level of inventory is calculated without changing the underlying parameters; safety stock policies, existing lot rules, standard lead times etc.

These parameters become the 'givens'. People are expected to reach the target inventory levels without changing the underlying parameters. Yet safety stocks, lead times and lot sizes are the very parameters that must be changed if significant inventory reductions are to be achieved.

The question of how much inventory is present is not as obvious as it seems. The inventory level represents a snapshot taken at some instant in time. The actual level of inventory varies over time and, therefore, the value obtained is a function of when we choose to take the snapshot.

Using the generally accepted approach of considering only end-of-month inventory levels, excessive emphasis is laid on the pattern of shipments. However, the inventory status is grossly overlooked during the month, which if observed, would present some startling results.

The month end spurts in shipping activities is a result of 100% management technique of measurement. The inefficiencies associated with operating in this manner can be sizeable indeed. In addition to an increased average inventory investment, the uneven workload takes its toll in overtime, product quality and morale problems related to the end-of month panic.

The long time spans between successive inventory shipping activities causes the material to sit unused. This status of material not only occupies floor space, but also forces the material handlers to detour around standing stocks and the increased effort on their part brings in slackness due to

human inertial tendencies. The side effects are the problems that were just discussed.

This idea then demands a streamlined approach towards inventory reduction and production efficiency improvement. These include the following steps in hierarchial order:

1. Preparation and involvement of people.
2. Organization of workplace.
3. Streamlining of production activity with interdependent coordination.
4. Attention to work detail.
5. Dedication to excellence.
6. Constant practice towards cultivating improved procedures of tooling, material handling, and production operations.
7. Quest for making changes and practice of preserving improvement.

These seven steps are not an end by themselves. There should be an ongoing trend towards improvement by seeking out problems in production and inventory management until the production efficiency is enhanced to the topmost limit of achievement.

The following list includes potential areas and objectives for improvement of productivity.

1. Lower WIP inventories.
2. Improve direct labor productivity.
3. Improve indirect labor productivity.
4. Lower material cost.



5. Increase plant thruput and utilization.
6. Improve customer service.

The next chapter looks at the approaches to these problems through the methodologies of push/pull scheduling. Emphasis has been laid on MRP due to its prominence in manufacturing industries. Also included is a historical perspective and introduction to the Just In Time Production System.

## PRODUCTION SYSTEMS - A COMPARISON

The key to successful application of scheduling technology is to understand its impact on the product flow well enough to custom fit it to the manufacturing process that is to be scheduled. Every product structure tree can be approached on the basis of supply or demand. If the resources are critical to the process of production, then PUSH scheduling and execution will provide the planning control. If the customer demand is the matter of concern, then PULL scheduling will be of paramount importance. By definition, a "push" system is one where orders are launched and 'pushed' through the factory to meet some established due date. A "pull" system is one where orders are placed at the end item level and work is "pulled" through the factory to satisfy the demand for the end item. However, it is realized that due to the uncertainty in demand, and the variability in production, both, push and pull methodologies need to be incorporated in implementing flexibility in the shopfloor process. The extent to which a production system is implemented depends on the nature and the limitation of the process itself as demonstrated in Table 3.1..

### MATERIAL REQUIREMENTS PLANNING:

The top down backward scheduling ( scheduling from finished goods to raw materials ) logically converts the customer demand into the anticipated lower level material requirements. However,

**Table 3.1**  
**PUSH - PULL SYSTEMS**  
**EFFECTIVENESS COMPARISON**

SITUATION	PULL	PUSH
1. DEMAND DRIVEN SCHEDULING & EXECUTION	GOOD	FAIR
2. LONG THROUGHPUT TIMES IN MANUFACTURING	FAIR	GOOD
3. LONG LEAD TIMES IN PURCHASING	FAIR	GOOD
4. ALLOCATION/UTILIZATION OF CRITICAL RESOURCES	FAIR	GOOD
5. AGGREGATE RESOURCE REQUIREMENTS	GOOD	FAIR
6. STAGE INTERDEPENDENCY	GOOD	FAIR

the basic order driven logic of MRP generates schedules that defy the smooth flow of product, when executed by the exclusive use of pull authorization. The authorization to produce or procure components must precede their parent item's need date by the component's respective replenishment leadtimes if they are to be available as scheduled by MRP in support of smooth product flow. Since authorization comes from the lower level in anticipation of higher level needs, the execution must utilize push logic.

The problems in execution arise when higher level needs change after the lower level execution has already begun, or when the lower level execution cannot, or does not proceed as scheduled. These problems are not a result of flaws in the basic scheduling logic. Their disruptive impact on product availability can be buffered by working around the scheduling logic, but the problems remain. In fact, they are usually amplified because many of the buffers expand the replenishment lead time, which increases the likelihood of changes within the leadtime.

The source of most higher level changes is customer demand. Improved management of customer demand within the cumulative replenishment leadtime is the only solution. All other approaches of this problem provide only temporary relief, increase costs and usually increase the problem.

A two pronged approach can achieve the solution.

- i) Acquire a better understanding of the nature of customer's needs.
- ii) Reduce the replenishment leadtime.

Increasing the safety stock in finished goods inventory for the make to stock products and level one inventory for finished or assemble to order products is the most popular method for buffering demand changes. This symptomatic treatment of the problem increases inventory investment and authorizes production before it is truly needed, which also increases leadtime, distorts priorities and consumes resources before they are really needed. In addition, every time, the safety stock level is changed, the result is just like another change in demand.

The uncertain reliability of manufacturing processes and the inconsistent validity of the schedules (schedules are not executed according to plan) are the two key factors that degrade the execution of the lower level schedules.

MRF logic treats each item independently except for its demands. It does not consider any joint impacts or interdependencies other than those in the bills of material. It ignores aggregate capacity constraints and economies which may be derieved from sequential production of similar products. It provides a time phased picture of material requirements that is valid only when adequate capacity is available. There may be additional economies available from grouping and sequencing products at intermediate levels in the product structure. This

grouping cannot be accomplished by MRP. Additional methods are necessary prior to the use of MRP to group and schedule some of the items in the product structure and to insure capacity availability, if MRP schedules are to be valid.

Grouping and sequencing of intermediate and lower level items must be done explicitly in certain manufacturing environments. MRP cannot be used to schedule production of these items, but it can be used to schedule availability of their components. It can also be used to aggregate and offset the higher level demands that must be met by these intermediate schedules. The scheduling at this intermediate levels constitute push planning, and it is these intermediate or lower level schedules that control the planned availability of higher level items. The material flow is determined from lower levels and is pushed to the higher levels.

In the entirety of planning/scheduling, the MRP logic schedules discrete lots by netting requirements, sizing production lots, and offsetting these lots to generate the lower level component requirements necessary to produce those lots. As the lot size increases, the throughput time of that lot is increased, and the replenishment lead times of all the parents of that component are increased. However, the total throughput time of all lots will also increase, if changeover or set up times for the lot are significant. Increasing the run length or the lot size of a single item at any level is detrimental to the smooth flow of all items in the production tree. The only solution to achieve smooth flow and maintain total throughput is to eliminate

as much non productive set up or changeover time as possible.

However, the throughput will increase in any environment if the set up/changeover times are reduced. It is imperative to reduce lot sizes and as lot sizes decrease, the number of lots must increase, if the overall production rate is to remain the same. MRP becomes more and more tedious, as the number of lots increase (or lot sizes decrease). In repetitive manufacturing environments, it loses its applicability altogether in terms of scheduling individual lots. The increased lots actually substitute confusion for the necessary co-ordination required in the shop-floor production.

Dr. Orlicky, in his book on MRP (page 28), iterated that the economic lot sizing actually causes lumpiness in the schedule at lower levels. This lumpiness would then force these problems into the actual production process.

- i) Long set up times since set ups are done infrequently.
- ii) High WIP inventory because production runs are long.
- iii) Inconsistent production since the output required per period is not the same, thus contributing to reduction in process reliability.

All these inconsistencies are depicted in the demand for steel Z (figure from MRP book, Orlicky, P28), Figure 3.1.

The comparison of Inventory systems between Japan and U.S. demonstrates the emerging interest of manufacturing executives throughout the nation in taking advantage of the Just In Time system. This comparison is presented in Table 3.2.

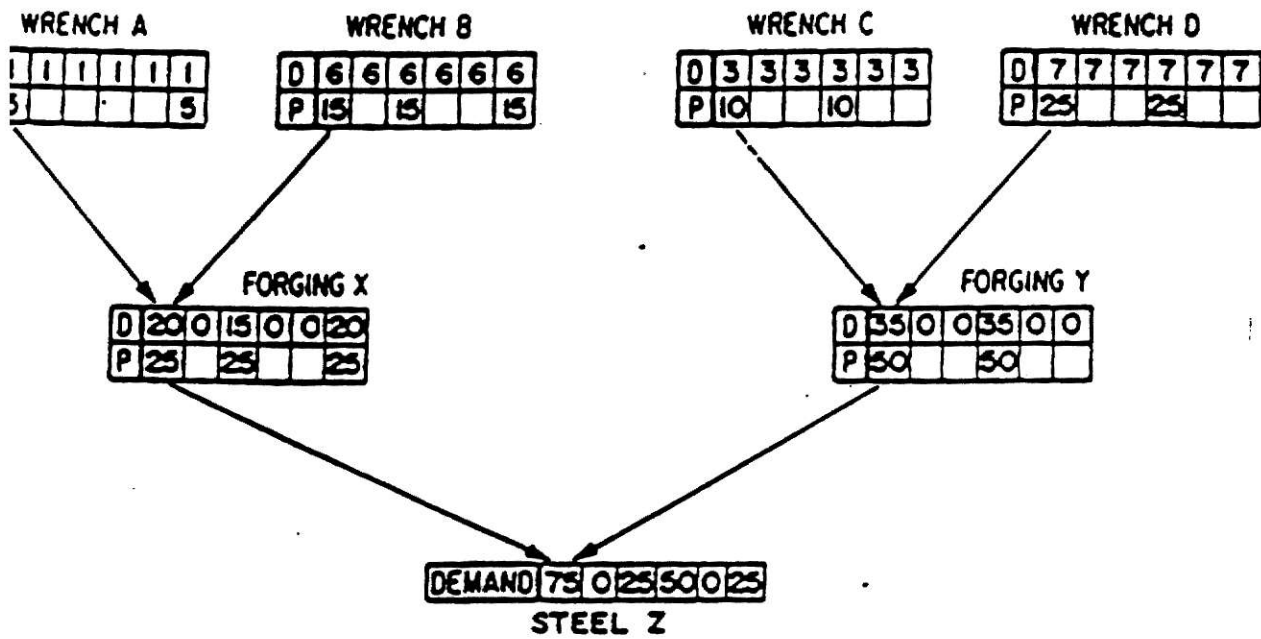


Fig 3.1 : Causes of "Lumpy" Demand



Table 3.2 : INVENTORY SYSTEMS - HOW THEY STACK UP

Inventory Control In Japan Tends To Start With:	Inventory Control in The U.S. Tends To Start With:
Small incremental improvements evolving into large systems as needed.	The implementation of a large computer based system to effectively manage inventory.
The line worker, who initiates many ideas leading to improved inventory control.	Upper management does all the initiating.
An overall point of view, recognizing that inventory control is inseparable from quality control, productivity, etc.	The isolation of the material handling problem or inventory control problem from other plant operations.
Personnel transfers across functional lines.	Little cross-fertilization of job functions.
Long-term stable relationships with suppliers.	Switching suppliers every so often to get the best price.

### JUST IN TIME PRODUCTION SYSTEM:

It is surprising to note that the JIT production system pioneered at the TOYOTA plant in Japan works inspite of the lack of forecasting abilities of the lower and intermediate levels of the various processes connected with the product development. The company pursues a level production plan over a relatively long period and its master production schedule is frozen for a month.

With this type of production planning and scheduling, the preceding processes do not have to be concerned about having to adjust their capacities. This is especially true for a manufacturing process that operates in an environment where the demand for its product is stable. Its process can eliminate the need for buffer stock, and, in turn, reduce its over all inventory levels.

Now consider a manufacturing company with these two attributes:

- 1) Production levels not stabilized.
- 2) Changing master production schedules.

If JIT is instituted in such a company, then it is likely to bring about drastically worse results than MRP because of its nearsightedness and consequently products will not be produced in time because of the lack of sufficient capacities and inappropriate dispersion of resources.

This case demonstrates that JIT requires a perfectionist attitude and the necessary pre-requisites for its implementation follow (Figure 3.2):

Fig 3.2 : JIT - PREREQUISITES

1. FLEXIBILITY - WORK CENTERS, EQUIPMENT AND PROCESS.
2. STABLE MASTER PRODUCTION SCHEDULES.
3. VERY HIGH RELIABILITY - PROCESS + OPERATIONS
4. HIGH PROCESS YIELDS - NEGLIGENT SCRAP, NOT LOW.
5. AUTOMATIC SETUPS - HIGHLY RESPONSIVE TO  
PRODUCTION SCHEDULE  
CHANGES.
6. MULTIFUNCTION WORKERS - FLEXIBLE WORK RULES  
TO HOLD COORDINATION
7. GROUP APPLICATION & COMMUNALITY IN  
APPROACH - " NON STANDARDIZING ".
8. COMMITMENT TO ACHIEVE HIGH QUALITY &  
CARRY OUT CONTINUOUS IMPROVEMENT  
AND SEEK PERFECTION.

These sum up into a crisp and a clear definition of JIT (Hall, 1983).

"Just in Time is attitudinal , a management style and set of practices, a belief, and a set of techniques."

This shows that MRP approaches a forceful soliciting of external demand, and in contrast, JIT requires a dedicated commitment to the available resources.

The following chapters deal from definition to implementation techniques of JIT.

## JUST IN TIME PRODUCTION SYSTEM

The idea of JIT was stated very clearly by a General Motors foreman with deliberate lack of grammar- " You don't never make nothin and send it no place. Somebody has to come get it ." (Robert Hall, page 39).

This idea lays emphasis on the production of only those parts that are needed somewhere else and not for stock piling them. Why should parts be produced, if they are not needed? So, produce only what is required in the necessary quantities.

Toyota's production system can be considered to be a (fixed volume) pull system operating on stock in the pipeline, connecting the work center where it is made (source WC) with the work center where it is used (destination WC). It has two major characteristics :

1. Synchronized material movement :

$$\begin{aligned} &\text{Rate of production at source WC} \\ &= \text{Rate of consumption at destination WC.} \end{aligned}$$

This coordination can take care of controlling the production rate in response to demand variations.

2. The total amount of inventory in the pipeline (WIP inventory) is kept at a controlled level. (Fixed volume pull system).

As the amount of pipeline stock is reduced, the frequency of removal from the output end increases, with reduced lot sizes. The removal of stock for use becomes a signal on the other end in order to keep the users supplied. So, the effect ceases to be one of controlling an inventory system at all.

Its necessary prerequisites are, the substantial revision of equipment and a well co-ordinated plant layout. The objective is to achieve a well coordinated production on a flexible line by efficiently controlling the range of jobs assigned to each worker. Routings must be defined and fixed so that each part has a clear path through production. In each plant, there is only one source location for each part.

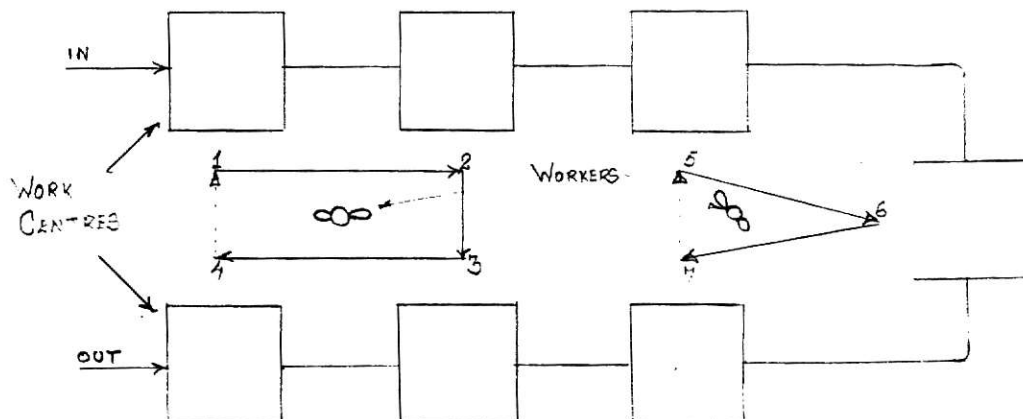
#### LAYOUT DESIGN:

1. U Turn Layout: The machinery layout for Toyota has a U shaped material flow. The essence of this layout is that the entrance and exit of a line are the same position.

Its features:

- i) Flexibility to control the number of operators when adapting to changes in production quantities.
- ii) By keeping a standard inventory quantity at each machine, the unbalanced operations among workers will be visualized and improvements in the process can be accomplished.

It is depicted in the figure below:



## 2) DEDICATED LINES :

There has been a contrast among ideas of different authors in reference to this concept of layout. Jack Youngkin, in his paper, "Implementing Zero inventory production in a job shop manufacturing environment" supports this layout by offering these advantages:

- i) Lead time to complete a part may be reduced upto 90 percent, greatly enhancing flexibility.
- ii) WIP inventory can be subjected to multiple revisions.

However, Yasuhiro Monden in his book ( Page 104 ) criticizes this layout with the following reasons:

- i) Inability of reallocating operations among workers to adapt to changes in demand.
- ii) When machines are set out in linear form, each line is independent from other lines so the reallocation of operations among workers in accordance with demand for products often requires fractional number of workers ( eg. 8.5 people ). So either the worker will have some amount of waiting time or excessive production will occur.

The problem of fractional numbers of workers at Toyota was overcome by combining several U-form lines into one integrated line. Using this combined layout, the allocation of operations among workers in response to production changes can be accomplished by altering the work allocation itself. This way, a

worker's responsibilities will be increased as demand reduces (cycle time increases) and will decrease when demand increases (cycle time reduces). In addition, JIT does not support bird cage layouts (Figure 4.1) and isolated island layouts (Figure 4.2). Bird cage layouts are classified by allocation of one worker to several identical machines in cell. Isolated islands assume the existence of a multi-function worker in the cell with the responsibility over different types of machines.

#### BIRD CAGE LAYOUTS - DISADVANTAGES:

- i) Production quantity/worker is increased resulting in an increase in semi-finished or intermediate inventory, produced at each work station.
- ii) Production balancing between stations is difficult to achieve.
- iii) Lead time to produce finished goods rises dramatically.

#### ISOLATED ISLAND LAYOUTS-DISADVANTAGES:

- i) Difficult to attain total balancing of production among various processes.
- ii) Since inventory can exist among isolated islands, waiting time of a worker will be absorbed in producing this inventory.
- iii) It is difficult to reallocate operations among workers.



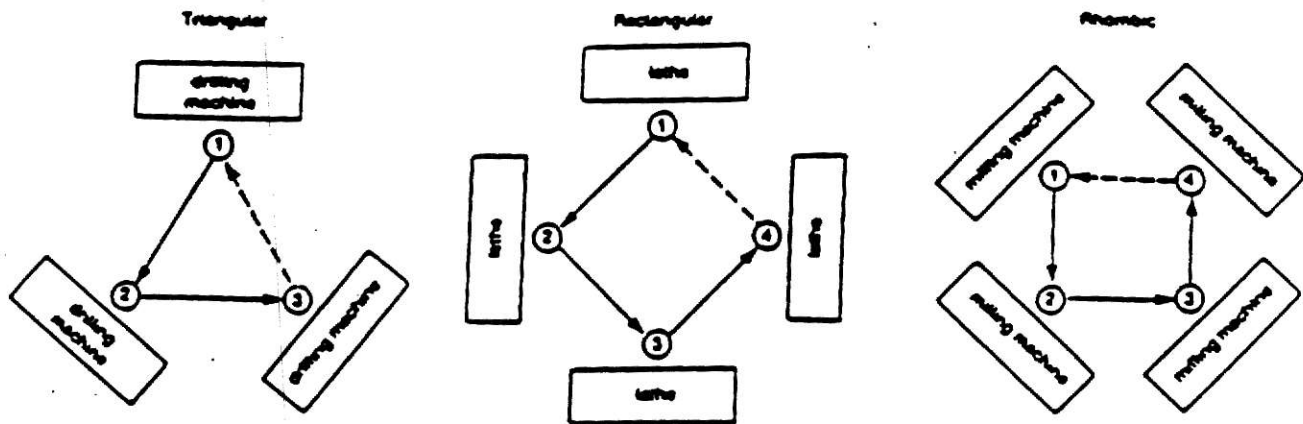


Fig 4.1 : Types of Bird Cage Layouts

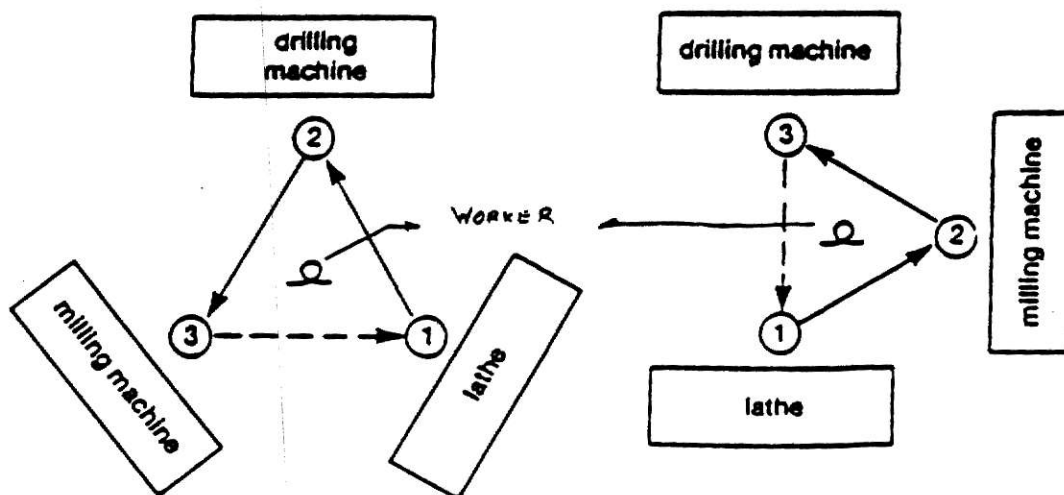


Fig 4.2 : Types of Isolated Island Layouts

#### WORK CENTERS:

Each work center is defined and organized, so that inventory is held only at the work centers and not in stock rooms. Each WC has an inbound stock point and an outbound stock point. Assembly lines have one or more inbound stock points that serve as staging areas, where material is organized for positioning in exactly the right location for easy access during assembly work. In effect, the entire plant assumes the organization of a stock room. This is necessary if all active inventory is to be kept on the plant floor without confusion. The next three figures, (Figures 4.3,4.4,4.5) illustrate the development of plant floor to use the card system. The concept is extended to the suppliers who are considered to be work centers which happen to be shared with other companies, and the card control system extends to them just as if they were inside the plant. Two kinds of cards are used - move card and production card.

#### MOVE CARD (Figure 4.6):

It authorizes the movement of one part number between a single pair of work centers. This card circulates between the outbound stockpoint of the supplying WC and the inbound stock point of the using WC. This card is always attached to the standard container of parts when it is moved to the using WC. It includes following information:

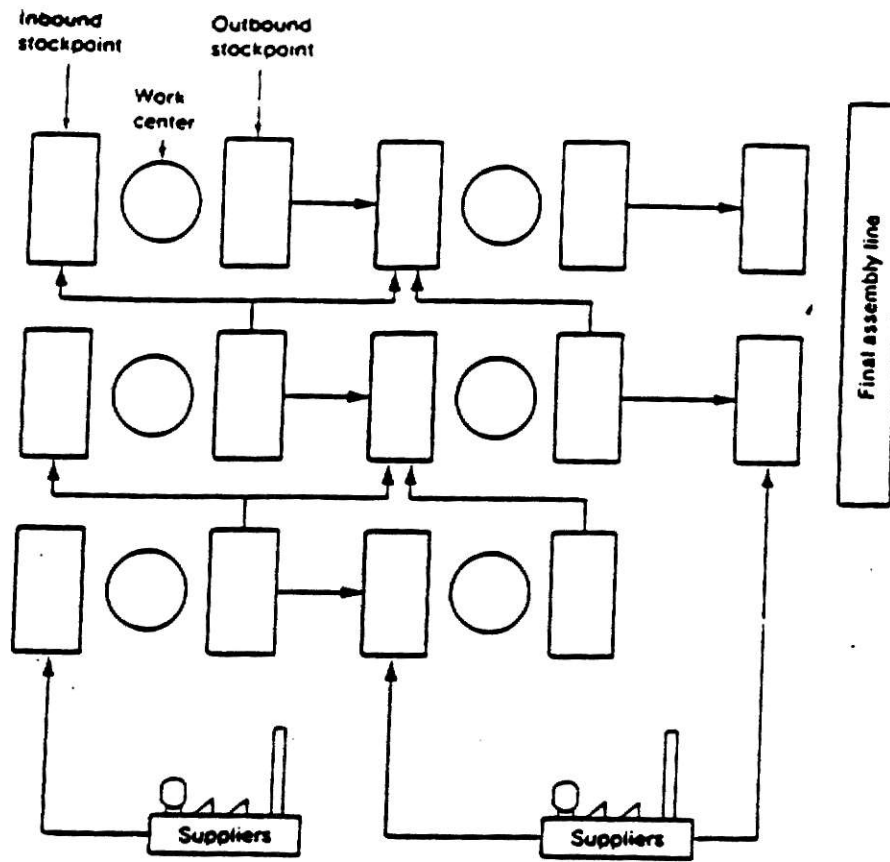
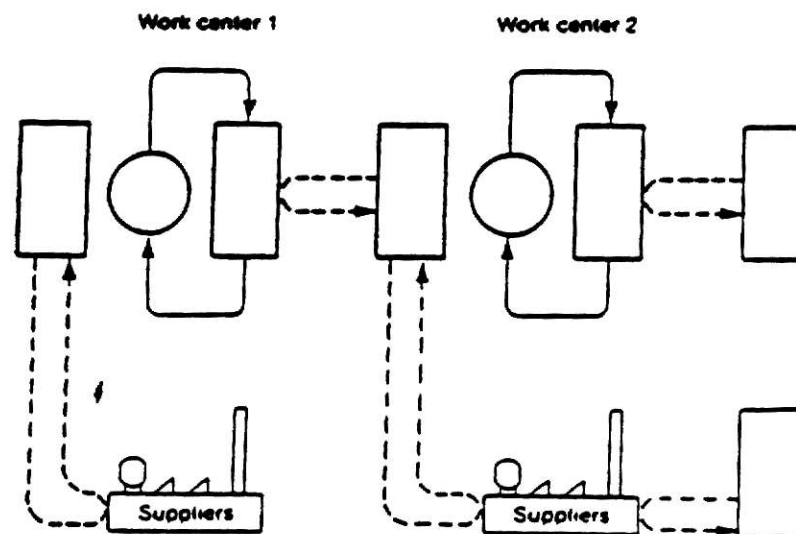


Fig 4.4 : Flow paths of cards (signals)

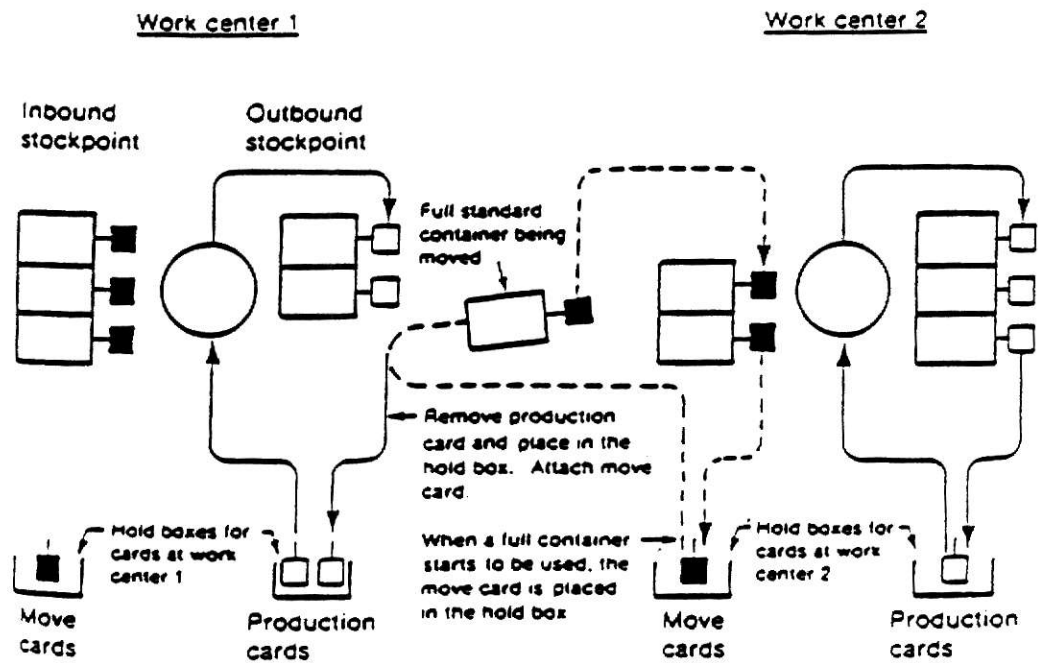


- Move cards. These circulate between work centers as signals to advance standard containers of parts
- Production cards. These circulate at the producing work center to signal the need to replenish the outbound stockpoint with a standard container of parts

Fig 4.5 : Kanban cards used as pull signals

Using only two work centers, the paths of the cards can be shown in more detail:

- Move card
- Production card
- Move card path
- Production card path



FROM SUPPLYING WORK CENTER #52 PAINT	PART NO A575 GAS TANK MOUNT	TO USING WORK CENTER #2 ASSEMBLY
OUTBOUND STOCKPOINT NO 52-6	CONTAINER TYPE 2 (RED) NO IN EACH CONTAINER 20 CARD NO 3 NO CARDS ISSUED 5	INBOUND STOCKPOINT NO 2-1

Fig 4.7 : Typical production card

WORK CENTER #52 PAINT PART NO. A575 GAS TANK MOUNT PLACE AT STOCKPOINT NO. 52-6 MATERIAL REQUIRED: PAINT #5 ST. BLACK PY 372 STAMPING FOUND AT WORK CTR. 31 PRESS SHOP STOCKPOINT NO 31-18
--

1. Part Number.
2. Container capacity.
3. Card Number.
4. Supplying WC number, its outbound stock point number.
5. Using WC number, its inbound stock point number.

#### PRODUCTION CARD (Figure 4.7):

It authorizes the production of a standard container of parts to replace one just taken from an outbound stock point. These cards are used only at the supplying work center and its outbound stock point. It has information such as :

1. Part number to be produced.
2. Container capacity.
3. Supplying WC number, its outbound stock point number.
4. Card number.
5. Materials Required

- i) A short BOM of needed parts.
- ii) Outbound stock point locations from which to get parts.

#### METHOD OF OPERATION:

When the container of parts is selected for use from inbound stock point, the move card is detached and placed in a collection box. It is picked up and taken back to the supplying work center as an authorization to get another container full of parts. Move cards therefore circulate between work centers. Each card

designates one part number.

When the move card is brought to an outbound stock point to get parts, the production card is removed from the standard container selected. The move card is attached to the standard container, and it is transported back to the inbound stock point of the using work center ready for use. The production card which was removed is placed in the collection box at the supplying work center. From time to time, workers collect these cards. Each production card collected is an authorization to make another standard container full of parts to replace one that was just taken.

WORK RULES :

- 1) Either a move card or a production card must always be attached to containers holding parts.
- 2) Using work centers must always come get the parts from supplying work centers, or signal the supplying work centers for parts using the move cards. Never transport a container of parts without a move card.
- 3) Standard containers are always used. Never use non standard containers or fill the standard containers with non standard number of parts.
- 4) Only produce a standard number of parts when an unattached production card authorizes it. Always attach the production card to the full container when it is placed in the outbound stock point.

If these rules using the cards are followed, the system provides a very simple pull system by which all material flow is synchronized in moving forward from raw material stage to final assembly stage.

The production control department gives the final assembly schedule to the final assembly area. It may be the same as the final assembly schedule originally planned, or it may deviate slightly from that schedule. For example, the auto industry assembles units only to schedule. They may receive order cancellations and need to make detailed adjustments in the final assembly sequence run. As long as these deviations do not exceed the pre-established limits of tolerance, there is little trouble pulling the right parts to build the sequence of units assembled.

All workers in the system have the obligation to provide parts to those who need them. Everyone must be able to come get what they need when they need it. It requires a total coordination and flexibility among workers to follow a schedule with small deviations from planned production.

#### PRODUCTION CONTROL:

1. To meet their schedule, final assembly workers withdraw parts as they need them from the work centers that supply them.
2. Since many parts come from suppliers to final assembly, as a practical matter many of the cards are collected and given to the truck drivers delivering from suppliers. These cards



returning to suppliers are the request for the amount to be delivered with the next load. This is one way of enlarging the plant production control sphere to include workers in the vendor plant. If the vendor uses the kanban system, the vendor's workers are controlled by the main plant.

3. The work centers supplying the final assembly line make just enough parts to replace those that have been taken.
4. Continuing this way, each work center withdraws parts as needed from the work centers supplying them. This continues in a chain all the way back to the suppliers.
5. Much of the move card transport is actually performed by the material handlers. The workers use the cards as a signalling system.

#### EFFICIENT PLANT CONTROL

It takes a great deal of plant development just to get to a point where a pull system will work in a very basic way. The pull system should be capable of controlling the inventory level of any part number at any point of use on the plant floor. Each part should be made at only one work center, but it may be used at several. So, the number of production cards in use is set to allow the producing work center to operate so as to barely be able to cover the needs of using work centers when they come to get parts.

Most of the inventory should be held at the outbound stockpoints, but this may not always be possible. The amount of inventory held at the inbound stock points and in transit

reflects the state of development of material transport and also the need which the using work center may have for parts before it can be resupplied. The number of move cards issued for each part number between each pair of work centers covers this.

Since one card goes only on one standard container, the total number of cards issued for each part number is proportional to the amount of WIP or pipeline stock allowed for each part number. This is further subdivided according to how many production cards are issued to the producing work center, and how many move cards are issued for each work center pair. The following points aid in achieving an improved adjustment of inventories:

1. Issue the cards at the start of a frozen schedule period.
2. Withdraw any cards that allow any inventory in excess of what is needed to buffer the imbalances between the supplying and using work centers for a specific part. This often is done by department managers.
3. Withdraw one or two more cards from the system and analyze the cause of the problems that occur. Withdrawal of production cards will aid in studying production work center problems, and, withdrawal of move cards will aid in the study of using work center or of material transport problems.
4. When cards are initially withdrawn from a pipeline in which stock barely allows coverage of operations, everyone has to do some extra work, usually overtime, but this is not the real problem.

5. Involve people in a coordinated effort in solving these problems.
6. Incorporate changes in work methods, equipment, or scheduling activities and that are least expensive.
7. When the production seems to be running smooth, again withdraw one or two cards and experience the entire process again.

The ideology is that problems should be made visible so everyone can see them. Develop organized ways to attack the problems as they are revealed. The existence of a pull system does not reveal problems by itself. It is the reduction of inventory which does it.

#### OTHER VARIATIONS OF MATERIAL TRANSPORT SIGNALS:

If the same part is made by the same people every day, the information on the cards soon becomes unnecessary. Pull signals (Kanban, as referred in Japanese) are therefore given by colored washers, chips, plastic markers, electronic signals, and the containers themselves. The containers may be only colored or they may be tagged with much more information. In modifying the system, it is important that it should easily provide the function of keeping a limit on the pipeline stock as well as providing demand signals (not always done when practice becomes sloppy).

This list provides information about other types of kanban used for a variety of production activities:

**EXPRESS KANBAN :** Shortage of part at succeeding work station or when the preceding work station has not been sufficiently replenished with stock. This might happen when either the preceding work station is behind schedule or succeeding work station is ahead of schedule.

**EMERGENCY KANBAN:** Issued temporarily when additional inventory is required to cover defective units, machine troubles, spurt in weekend operations or extra fittings, insertions.

**JOB ORDER KANBAN:** Used for each job order pipeline and issued for each job order.

**THROUGH KANBAN :** Used where two or more processes can be considered as a single process as they are very closely connected. Can also be used where each piece of product produced at a line can be conveyed immediately to the next line by a chute, one at a time. Also applicable to such processes as heat treatment, painting, electroplating, etc..

**CAR OR TRUCK :** The vehicle itself can play the role of Kanban when used for transport of large units such as engines and transmissions.

**LABEL :** Specifies which parts, how many and when the parts will be hung on hangers set up at a smooth interval on a conveyor belt. Also applied to final assembly line to instruct the sequence schedule of mixed models to be assembled.

**FULL WORK SYSTEM:** It is employed with automated machine processes and it is actually a system of triggers or limit switches to provide electrical control of parts transfer from the preceding (automated) process to the succeeding (automated) process with no manual intervention. These switches let the material flow resume only when the subsequent process needs the material.

As the workers become experienced, they will skip using production cards although this can lead to difficulty in keeping an upper limit on the amount of stock to be produced for each part at a supplying work center's outbound stockpoint. The workers follow a simple rule of stacking a fixed number of containers at the outbound stockpoint. If someone comes and takes two from a stack of four they know to make two more.

When using this one card system, the Toyota family companies often use a warning system with a triangular shaped marker.

These markers themselves have the part number painted on, and

they slip between the boxes stacked in the outbound stockpoint. When the box on top of the signal marker is removed, the marker is placed on the tree, which is a very visible location so if they are not already running that part or setting up for it, they should be. A marker of this type, or a set of production cards placed in a visible place, is commonly referred to as 'Parts hanging'. This is analogous to safety stock but it is not exactly the same. The amount of buffer is the amount needed to balance the production rates at consecutive work centers.

#### OBSERVATION:

In fact, the existence of the signal markers is evidence that much potential may remain for improving the methods of production. The next objective is to advance to using the card system or its equivalent without signal markers. Beyond that the objective is to not even use those but to remove inventory until cards are no longer necessary. Once the material flow becomes smooth, direct transfer of material between work centers becomes feasible. Now the company is ready to deal with the link problems of full automation.

Sometimes the cards are used to record production counts. The move cards are most often used in this way to count the receipts of material from suppliers. At work centers, if production becomes regular like clockwork then a mechanical counter can be used to record production. However, the more regular the production becomes and the lower the inventory becomes, the less important it becomes to record all those counts at many different

points. Decisions would then no longer be made on the basis of requirements minus inventory.

A large company making a complex product must expect to have a lot of variations in the pull system. This is certainly true in the case of Toyota. They list 10 different kinds of cards in use in the system for various purposes .

#### COORDINATED INFORMATION:

Plants that feed many parts into one or two assembly areas have an electric 'scoreboard' in the middle of the plant, visible to the maximum number of people. Identical scoreboards are located at multiple points if desirable.

These boards or "andons", as they are called in Japanese, give information to help coordinate the efforts of the linked work centers. The board posts the cycle time of the units being assembled on each assembly line. Everyone can see which of the parts they are responsible for goes into each model. Considering that the parts are evenly dispersed among units being assembled, they can estimate whether they are producing faster or slower than the demand rate.

The boards also have signal lights indicating the basic status of each work center:

Green = Running

Yellow = Needs attention

Red = Stop.

This allows the workers to plan ahead on the parts requirement schedules. Most important, they should not continue production if the departments using their parts have stopped using them. If the final assembly areas stop and stay stopped, the fabrication areas also stop, sometimes without waiting to see that pull signals for material are no longer coming.

The scoreboard is very important for tracking actual assembly completions against the schedule. Where an electric board is not used, the same record can be posted on a blackboard or chart. Typically, these boards compare hour-by-hour cumulative completions for the day with what should have been completed by the schedule. Workers can then tell where they stand for the day.

The objective of this is to have the assembly area actually perform by a level schedule. It does no good for a level schedule to be planned if the assembly workers cannot hold it. So, they should strive to meet the cycle rates for each model and to deviate as little as possible from schedule. Doing so insures that the parts requirements coming to final assembly are held as level as possible.

Records are not kept, but frequently posted for all to see what the problems are either defects and their causes, or tool use, or skills and qualifications of each worker. The purpose is to allow the people as a team to control the shop floor quickly and easily. If an individual tries to communicate well enough to control a complex production department, things are always limited by both his ability to acquire information and to



communicate it. Therefore the principle is to communicate as much information as is possibly useful as soon as it is acquired, without delays for consultation or even for data processing, unless it is absolutely necessary. The data and communication lags must also be covered by inventory.

As the plant becomes more automated it becomes possible for a single worker or a team of workers to serve a large bank of equipment. They can be assisted by signal lights located directly on the machines as well as on scoreboards. This system allows workers to service a shop floor without much time spent figuring out what to do. Operators, maintenance people, and material handlers can all take their cues from the lights, scoreboards, and other signalling systems. The objective is to keep pressing toward the goal, but there is more to it than production control.

## PRODUCTION SMOOTHING- SCHEDULING PRODUCTION TO VARIABLE DEMAND

Production smoothing follows the production planning in two phases. The first phase involves the adoption of proposed schedule to the monthly demand changes during the year and the second phase involves the adoption of actual schedule to daily demand changes during the month.

The monthly adoption, based on quarterly plans proceeds as follows:

1. Preparation of MPS that instructs the averaged daily production level of each process in plant.
2. Based on a 3 month demand forecast and prepared every month.

The daily adoption uses kanban and sequence schedule for fine tuning the master schedule. The sequence schedule specifies the assembly order of various cars coming through final assembly lines eg., A-B-A-C and so on. This sequence is timed so that cycle time expires and one car is completed before another car on the schedule is introduced to the line.

The sequence schedule is communicated to the starting point on the final assembly line and not to the preceding process. This is the most characteristic aspect of Toyota's information system. Even in MRP, and also in other production systems, every production process must be informed of its activity schedule for the month. However in JIT (and at TOYOTA) the processes which

precede are given only rough monthly estimates of the quantities that will be required of them. From such monthly predetermined figures, the supervisor for each process can average the necessary workforce for the month in question.

So, when final assembly line assembles a car by using the parts stored beside the line, the withdrawal kanban for these parts from preceding processes will produce the sub level components as needed. As the kanban takes the production instructions backward, the preceding processes do not need their own particular sequence schedule in advance.

The sequence schedule is laid out in the monthly production plan that is based on MPS, (Master Production Schedule):

- i) About 2 months before the activity, the car types and quantities are suggested.
- ii) About 1 month before the particular month in question (of scheduled production activity), the detailed production is determined.

From this monthly production plan, the daily production schedule is set. Also, this information is communicated to the subcontracted companies simultaneously.

The smoothed production extends into two areas:

- 1) Average total production of a product per day.
- 2) Averaged quantity of each variety of product within the greater total.

Suppose we have a product with 4 different models A,B,C,D to choose from and its specifications are as follows:

Monthly Production = 20,000 units.

Month ( period ) = 20 days.

(This is short for a month, but TOYOTA follows 20 days instead of the regular 22 days schedule.)

Monthly Demand :-

A => 3000 units.

B => 4000 units.

C => 6000 units.

D => 7000 units.

Daily average = (Monthly production)/period  
= 1000 units.

Production Availability = 480 Min./Shift x 2 Shifts/Day  
= 960 minutes/Day.

From this data, the smoothed quantity of each model to be produced each day is found.

TYPE	MONTHLY DEMAND	DAILY AVG.	CYCLE TIME	UNITS/CYCLE
A	3000	150	960 MIN PER	3
B	4000	200	1000	4
C	6000	300	= 0.96 MIN PER	6
D	7000	350	UNIT	7
		-----		-----
		1000 UNITS		20 UNITS
		-----		-----

CYCLE TIME/CYCLE =  $0.96 \times 20 = 19.2$  Min.

Attaining the optimal sequence schedule of mixed production is a bit difficult, but Toyota is trying to determine such a schedule by heuristic software. A possible sequence for this example could be DCBA--DCB--DCBA--DCA--DCB--DCD--DCBA--

Even Toyota is trying to achieve perfection in sequencing that would entail using each part while keeping the withdrawal rate and quantity of withdrawal constant. Using kanban, the variation of consumed quantity of each part at the final assembly line must be minimized. The objective is to keep the rate of material consumption as constant as possible.

The monthly period is divided into 3 periods of ten days each. The order transfer proceeds as follows:

The ten day order from the dealer arrives to the Marketing Department about seven days prior to the commencement of the next period. The dealer anticipates the need for stock of products with standard specifications ie. those units that are being sold in large quantities. The manufacturing department takes a daily order (or daily alteration) from the marketing. The manufacturing then uses this ten days order to revise the smooth production plan for daily schedule. In other words, although the monthly predetermined production plan is based on a monthly sales forecast, the ten days order is based on the dealer's most up to date forecast.

Each day, the marketing department receives daily orders from all dealers throughout the sales network. Such daily orders are received about four days before the building of the product at

the final assembly line. The lead time is very short for the order. The dealer bases this order on actual customer demand, so all orders are up to the minute.

The computer in the marketing department classifies the dealer's orders according to the variety of the types and models of the product as specified. This classified information will be supplied to manufacturing, about three days before line-off of produced units. The importance of this information cannot be overstated, for it informs the plant of actual necessary production quantities. Just 2 days before the line off the Manufacturing prepares and releases the sequence schedule for its mixed model assembly line. As a result of this four step ordering process, a final model will roll off the assembly line only four days after the dealer has given his order to the marketing department; however the production lead time will be limited to only one day. The conveyance lead time and shipping will vary depending upon the geographic locations of different dealership outlets.

## BALANCED PRODUCTION WITH STANDARD OPERATIONS, MINIMUM LABOR.

Standard operations is aimed at production using a minimum number of workers. Standard operations achieves the objective of improved productivity through three goals as outlined:

1. Achieving high productivity through strenuous work .  
"Strenuous work" , a phrase coined at Toyota, means working efficiently without any wasteful motions.
2. Achievement of line balancing among all processes in terms of timing of production.
3. Maintenance of a minimum quality of WIP. or standard quantity of WIP.

To attain these goals, standard operations consists of cycle time, standard operations routine and standard quantity of work in process.

The standard operations routine is a standardized order of the various operations to be performed by each worker. The concept of cycle time is built into standard operations. The standard quantity of WIP contributes towards eliminating excessive in-process inventories.

The components of standard operations are determined mainly by the foreman (or supervisor) of the shop. He determines the labor hours required to produce one unit at each machine and also the order of various operations to be performed by each worker.

Generally, in other companies, such standard operations are determined by the IE staff. The standard operations are determined by the following:

- 1) Cycle time determination.
- 2) Completion time per unit determination.
- 3) Standard operations routine determination.
- 4) Standard quantity of WIP determination.
- 5) Standard operations sheet preparation.

#### CYCLE TIME:

It is the time span in which one unit of a product must be produced. Determined as,

$$\text{Cycle time} = \frac{\text{Effective daily operating time}}{\text{Required daily quantity of output.}}$$

This is sometimes determined erroneously by using the current machine capacity and labor capacity. Although, this gives a probable time span for producing one unit of output, it does not give the necessary time span needed for repositioning the workers. The effective daily operating time does not include allowances for machine breakdowns, idle time awaiting materials, rework, fatigue or rest time. Further, the required daily quantity of output does not include allowances (time) for defective items as unnecessary.. The consumption of such time is visible when it does occur in a process, and makes it possible to take immediate action to improve the process. If allowances are made for fatigue time and defective quantity, the cycle time will be long, while the objective is to reduce the cycle time to a



minimum.

#### COMPLETION TIME PER UNIT:

The completion time per unit of output is determined at each process and for each part. This time is always written on the part production capacity sheet (Figure 6.1), next page.

The manual operation time and the machine automatic processing time are both measured by a stopwatch. The manual operation time does not include the walking time at the process. The foreman determines the speed and the level of skill required for each manual operation.

The completion time per unit in the basic time column is the time required for a single unit to be processed. If more units are processed simultaneously, or, if a quality check is performed by random sampling, then the completion time per unit is written in the reference column.

The tool change column shows the exchange units that specify the number of units to be produced before changing the tool bit. It is also a reference to the set up time.

From the details filled in, the production capacity at each work center is determined thus,

$$N = \frac{T}{C + m}$$

N = Production capacity in terms of units of output.

C = Completion time per unit.

m = Set up time per unit.

T = Total production time.



#### STANDARD OPERATIONS ROUTINE (Figure 6.2):

After determining cycle time and the manual operation time per unit for each operation, the number of different operations that each worker should be assigned must be calculated. The standard operations routine is the order of actions that each worker must perform within a given cycle time.

It should be noted that the operations routine is the order of operations that a worker must perform in a given period of cycle time and the order of sequenced activities that need to be performed towards manufacture of final product. The preparation of standard operations routine is as follows.

1. The cycle time is marked with a red line on the operation time dimension of the sheet.
2. The approximate range of processes that one worker can handle should be determined.
3. The total operations time (of the worker) that approximates to the cycle time is computed from the part production capacity sheet. This also includes some slack time for walking between machines.
4. The manual operation and machine processing times for the first machine are drawn to scale, using the data from the part production capacity sheet. This is done for all other machines as well.
5. Since the operations routine was plotted to cover all the estimated number of processes, this routine must be completed

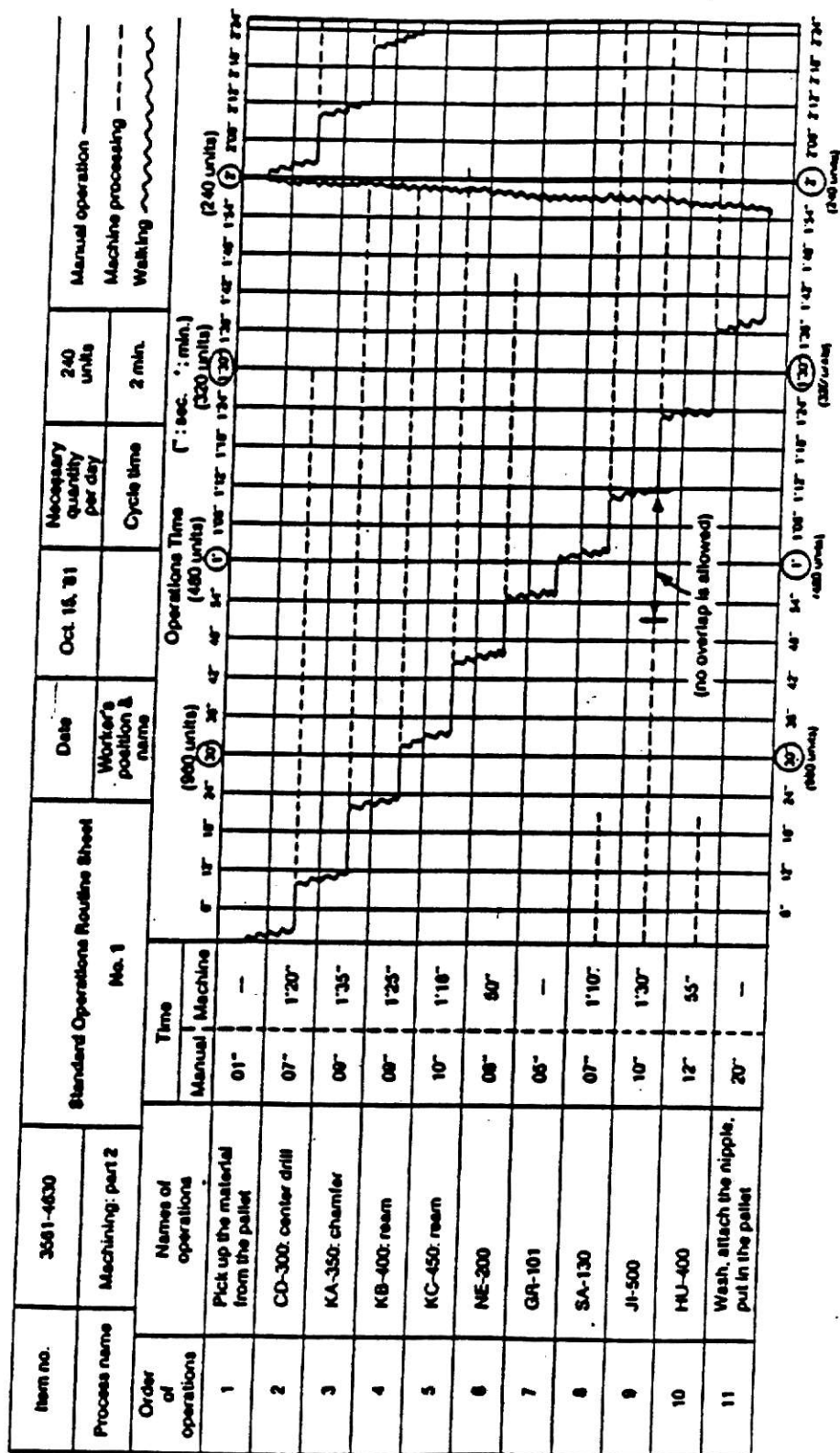


Fig 6.2 : **Standard operations routine sheet.**

at the initial operation of the next cycle.

6. If final wind up meets the marked line of cycle time, then the operations routine is an appropriate mix. If it ends before the cycle time line, consider whether more operations could be added. If this line overflows beyond the marked line, various operations of this worker need to be improved (in terms of sequence of activities, coordination of activities etc.)

If there is too much waiting time at end of operations routine, a double cycle time could be inserted to have simultaneous operations by two of three workers subject to same operations routine. This eliminates slack in cycle time (Figure 6.3)

#### ONE SHOT SET UP:

Machine sequencing is an important consideration in complex operation routines. Suppose, there are four different kinds of machines W, X, Y, Z in succession in a certain machinery process, and we assume that all these four machines are being handled by a multifunctional worker, and although he is now processing part A, he must next process part B in this process. He will never complete production of A and then stop 4 machines to complete a subsequent set up. He will begin set up of B while A is still in process. When the last of A has been processed at W, he will set up W, while A's get processed at X,Y,Z. Then he will load B on W and set up X, while A's are at Y,Z. Then the first B goes to X, a

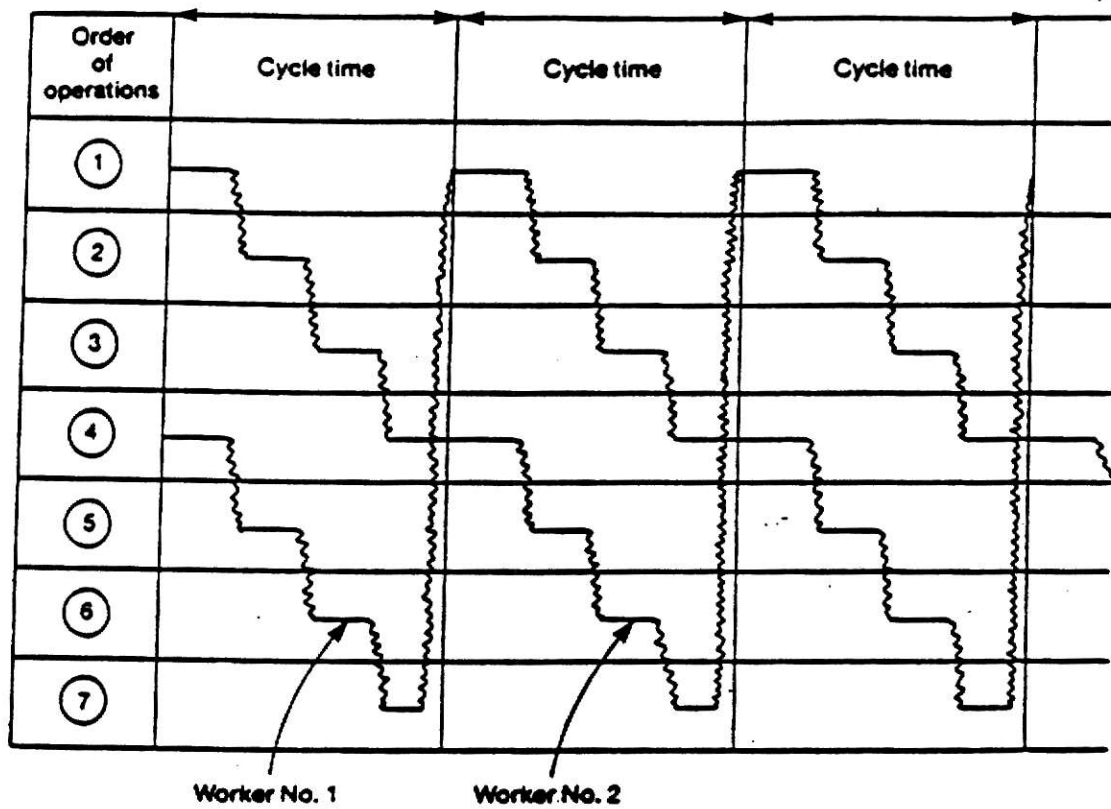


Fig 6.3 : Double cycle time for use by two workers.

new B is loaded at W and the worker sets up Y. Then the first B shifts to Y in the next cycle and the worker sets up Z. The setup activity schedule is shown in Figure 6.4. A very important point, is that all the set ups be reduced to the duration of cycle time or less.

#### STANDARD QUANTITY OF WIP:

It is the quantity of the work laid out and held between machines. Also included is the work attached to each machine. The quantity held in WIP is barely enough to keep the process line in balanced manner (keep the material movement synchronized), and without this quantity of work the rhythmic operations of various lines cannot be achieved. Consideration to keeping a standard quantity of WIP) is based upon two points.

1. If the operations routine is in accordance with the order of process flow, only the work attached to each machine is necessary; it will not be necessary to hold work between machines.
2. If the operations routine is in an opposite direction to the order of processing, it is necessary to hold at least one piece of work between machines.

The minimal quantities reduce holding costs, make defects more evident and aid in visual control in checking product quantity.

The standard operations sheet is the final item needed for standardizing operations at Toyota. It includes

- . Cycle time.
- . Operations routine.

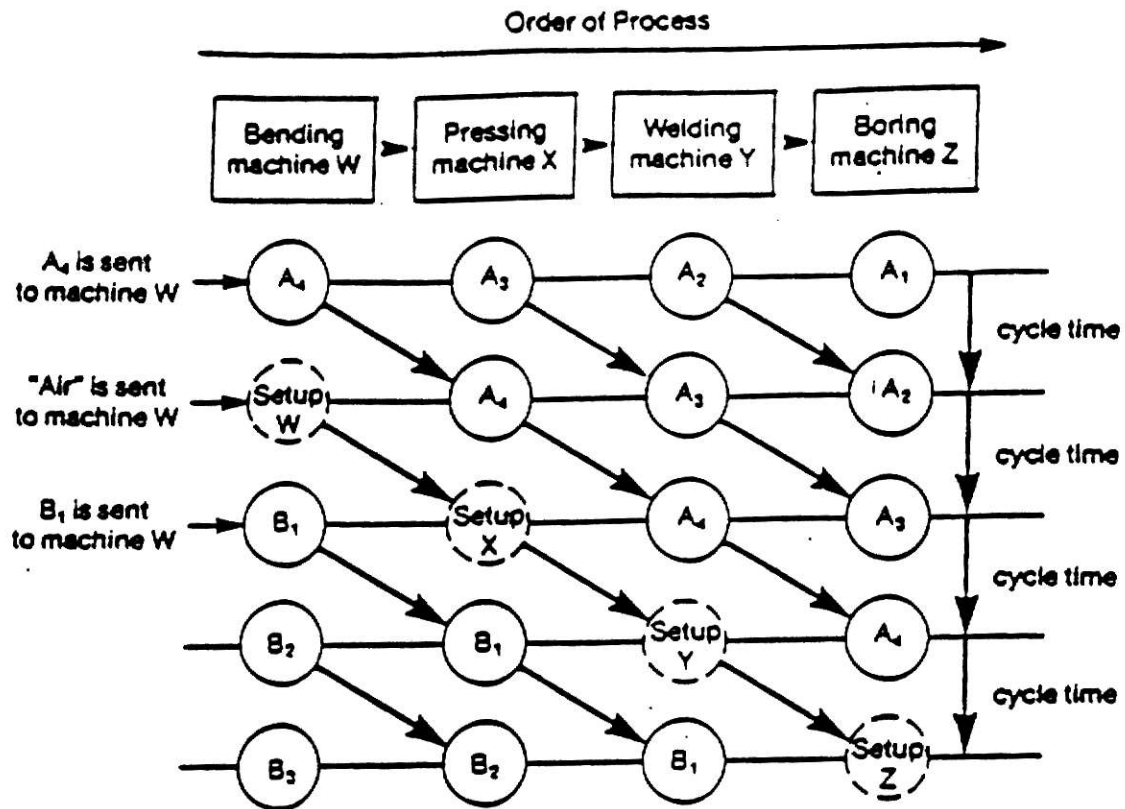


Fig 6.4 : One shot setup.

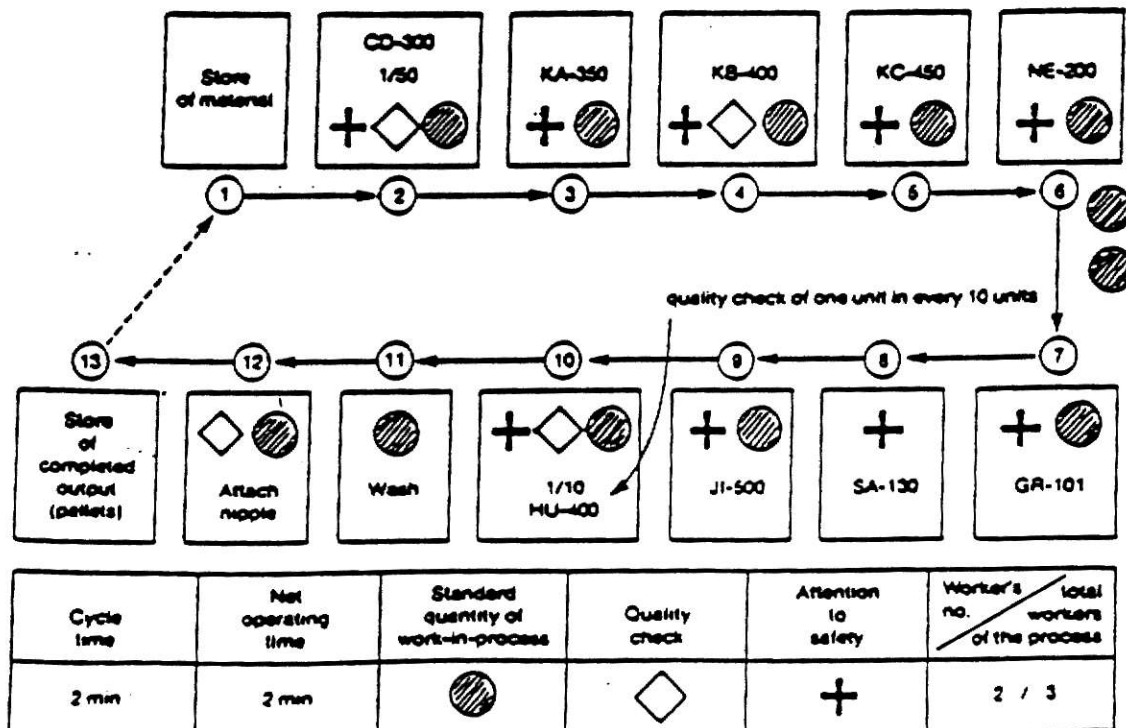


Fig 6.5 : Standard operations sheet.



- . Net operating time.
- . Position for inspecting quality.
- . Position for inspection of worker safety.

An example of a standard operations sheet is shown in Figure 6.5.

Finally, proper adherence to the standard operations routine by the workers must be followed, and any deviations be sought out and procedures revised. The remedial action might be those implemented by the supervisor himself. The monitoring of the actual versus the scheduled cumulative quantities of outputs at the completion of each cycle time in each process is depicted on the electric board, displayable to all the workers involved in a particular process. The standard operations should be subjected to consistent improvement as they are always imperfect.

## 6. IMPLEMENTATION CRITERIA.

Each company needs to start with the development of a basic pull system. It is not easy to determine the method and the extent of implementation of JIT on the existing processes of the plant. The degree of this difficulty depends upon the status of company's production when the implementation is started.

The implementation of JIT may vary from one company to another. While a few companies would only borrow a few ideas from JIT, others might consider comprehensive implementation in the entire plant.

The consideration to the following criteria and investigation of existing procedures of plant operation need to be carried out before actual implementation plans are initiated.

It should be noted that if all activities are changed at once, it is impossible to keep this approach co-ordinated. The following criteria, as proposed by Robert B. Stone, VP (materials management), General Motors Corporation:

1. Geographic concentration.
2. Dependable quality.
3. Manageable supplier network.
4. Controlled transportation system.
5. Manufacturing flexibility.
6. Small Lot sizes.
7. Efficient receiving and material handling.

8. Management commitment.

The list could be enhanced by addition of two more, as follows:

9. Curtailment of production inefficiencies.

10. Reduction of set up time.

Discussion of each of these criteria follows:

GEOGRAPHIC CONCENTRATION:

JIT requires very short transit times and in order to supply material with such short lead times, most of the suppliers have to be located close to the main plant. As an example, Toyota has most of its suppliers located within 60 miles of its plants. In contrast, GM has assembly plants scattered all over the U.S. and Canada. But again, it should be noted that many suppliers and their assembly plants are already clustered in the midwest and for these, the JIT should work, at least with respect to this requirement of geographic concentration.

DEPENDABLE QUALITY:

The manufacturing process must always be able to rely on receiving only usable parts from its suppliers. The Japanese concept is that every operation must regard the next operation as its ultimate customer, and pass only perfect products along. To do this, the Japanese quality control concept is based upon efforts to control the production process. Presently, the emphasis in American approach of production quality control is on inspection to pick out the bad parts.

There just is not enough slack to adjust production and JIT schedules to accomodate usable (or reworkable) bad parts. The emphasis on quality control begins with the questioning the need for safety stock. Alan E. Loeb1, Harris Corporation feels that US manufacturers must stop being dogmatic about the Japanese practices, cause by adopting JIT techniques and improving flow does not guarantee perfect results.

As an example, US manufacturers find product rejection levels of 1% or 2% acceptable. This attitude can sabotage efforts to achieve Japanese style results. He suggests looking at rejection levels in terms of parts per million. A zero defects concept becomes more imperative when a 1% rejection level is equated to 10,000 scrap parts for every one million produced.

Viewed in this manner, a 1% or 2% rejection level can be readily identified as an obstacle to achieving true JIT manufacturing. Receiving just the quantity of materials needed, and producing just the amount of product called for, will result in a shortfall if 1% rejection levels are tolerated. Safety stocks will be needed to make up for the scrap produced and so the JIT concept falls apart. This implies that raised assurance levels are needed to provide dependable quality.

#### MANAGEABLE SUPPLIER NETWORK:

General Motors Corporation has about 3500 suppliers for their assembly operations alone. The complexity of communications required is evident.

Reduction and simplification of the entire supplier network

by establishing long term relationships would reduce the lead time in the transportation of material.

#### TRANSPORTATION SYSTEM:

This involves short, reliable transit times. Japanese auto companies use only dedicated trucks ( single purpose ) to ship parts, and deliveries occur several times a day from each supplier at prescheduled times.

#### MANUFACTURING FLEXIBILITY:

JIT throws out the EOQ concept and forces drastic reduction in changeover time since there is no inventory to take up the slack or worry about model change.

Enhanced flexibility in the operations, improved coordination between interconnecting work centers, balanced production flow and the elimination of delays are the four conditions necessary for JIT implementation.

#### SMALL LOT SIZES:

The Japanese ideal is to achieve a lot size of one piece so that every time one vehicle is produced, one of each part in the vehicle is also produced.

Small lot sizes require daily assembly rates- that means daily master production schedules. Where the demand is level, level scheduling and fixed orders will work. But with fluctuating demand, a daily order policy is necessary.

This emphasizes an utmost accuracy on lead times. In addition

slashing set-up times is very critical for the efficient production management with daily master production schedules. In some cases, this reduction is accomplished through redesign of tooling and tool change procedures. However significant improvements can also be achieved through continued practice in performing existing set-up procedures.

#### EFFICIENT RECEIVING & MATERIAL HANDLING:

The formal receiving operations have to be eliminated. The traditional factory has only one receiving dock and materials move into the plant only after inspection. Even then material must be put into a formal, central storage area and then taken out again for production. When one department completes an operation, the work piece becomes part of inprocess inventory. The mismanagement of material hinders production.

JIT implementation requires abolition of inspection at purchase and multiple docks to allow material to go where it is needed as soon as it arrives without making an unnecessary detour to central stores. When one department completes its operation, workpieces will need to go immediately to next department. Records about material transfer will not be required, but can be maintained "on line" through indicators on material transfer devices.

#### MANAGEMENT COMMITMENT:

JIT requires a commitment to achieve high quality and carry out continuous improvement and seek perfection. This comprehensive commitment can be achieved only through a continual

involvement of everyone concerned to seek continuous production flow. This would be achievable only if the plant has a low labor turnover which means involvement of people with experience. It is difficult to make the fresh recruits understand the implications of the problems caused during JIT implementation.

#### CURTAILMENT OF PRODUCTION INEFFICIENCIES:

JIT requires a perfectionist attitude demanding a commitment to quality and excellence. It fights waste which affect every aspect of the plant: people, machines, material, space, time and the product itself. It fights inefficiency by:

1. Reduction in set up time.
2. Improved quality through reliable process and operations.
3. Flexibility in work centers, equipment and process.
4. Enhanced coordination among plant personnel and workers.
5. First class preventive maintenance to increase reliability of machinery. This is done on a continued basis.
6. Rearrangement of machinery and equipment into a compact arrangement to save space and improve process operation.

Only if all these ten criteria are satisfied can the existing plant and operations be satisfied for JIT implementation. The evaluation of existing plant and operation, based on the above criteria would at least provide insights into the causes for inefficiencies in existing systems. Also, if the prospective implementation is not favourable then, the existing system will at least be upgraded in performance with the ongoing improvements.

## JIT IMPLEMENTATION

The project of JIT implementation begins with the identification and the solution of problems in existing production system. Once the problems are identified, each problem then will be tackled by a selected team of engineers, supervisors and foremen. There is no structured approach towards the identification of problems and subsequent derivation of their solutions.

A variety of references propose a multiplicity of implementation approaches, but the actual plans depend upon the nature of the organization itself. Some of these references are discussed below.

The list at the end of page 14 includes potential areas and objectives for productivity improvement. Narrated again, these include,

1: Lower WIP inventories thru' reduction of

- Staging of kits in advance of manufacturing.
- Overloading production floor because of inadequate order release control.
- Work center queues.
- Obsolescence and inventory shrinkage.
- Lost orders and materials.
- Incomplete or inactive orders.
- Orders awaiting QC disposition.



- 2: Direct labor productivity improvement through reduction of
  - Idle time due to material/tool shortages.
  - Idle time due to machine breakdowns.
  - Set up/changeover time.
  - Overtime activities.
  - Rework on bad parts/components.
  - Labor spent on wrong priorities.
  - Shop congestion.
- 3: Indirect labor productivity improvement through reduction of
  - Expediting activities.
  - Modular software design (for computer controlled machines.)
  - Material handling movement and storage expenses.
4. Lower material cost through reduction of:
  - Vendor expediting.
  - Outside processing costs.
  - Rework cost.
  - Packing and shipping cost due to standard shipments.
  - Packing and unpacking cost (unpacking vendor's packages and packing for customer).
- 5: Increased plant thruput through:
  - Enhanced flexibility in operations.
  - Improved coordination between interconnecting work

centers.

- Balanced production flow.
- Elimination of delays.
- Integrated and flexible line layout for smooth material handling.
- Maintaining smooth production rates and reduce variability in production levels.
- Increase tool and machine availability due to better preventive maintenance.
- Effective production control.

6. Improve customer service through:

- Backorder reduction.
- Quality Improvement.
- Reduction in customer lead time.
- Reduction in split and partial shipments. Split shipments are shipments in two consignments. Partial shipments are also shipments in two consignments, but shipment is cancelled after the delivery of first consignment.

Y. Monden, in his book, says that waste will be found in men, machines, and management. He suggests,

1. Refinement of manual operations to eliminate wasted motion.
2. Introduction of new or improved machinery to avoid uneconomical use of manpower.

3. Better management of materials and supplies to provide an improved economy.

The improvements in manual operations would include elimination of totally redundant operations, and improvement of operations that are inefficient but necessary under existing operating procedures. Redundant operations such as waiting for materials, stocking of intermediate products and WIP stocking need to be eliminated. To eliminate such operations, it is necessary to make changes in line layout or arrange for the vendor items to be delivered unpackaged, either by more efficient packaging techniques or improved product design. One possible consideration is special design of the shipping containers. Even though the recommendations for improvements are provided, the actual improvement programs will depend upon the existing layout, operations and processes of the particular plant under consideration. Monden recommends:

- . Move supplies of parts closer to the worker or introduce chutes to shorten walking distances.
- . Use smaller pallets that can be placed beside workers who need only a small number of parts at a time.
- . Redesign a tool to eliminate the wasted motion in changing it from one hand to another.
- . Make it easier to pick up tools by hanging them in racks with their handles uppermost.
- . Introduce simple tools to streamline operations.
- . When a worker operates more than one machine, locate the

on/off switch between two machines so he can push it while he is walking from one machine to another.

Konz, in his book (iii), follows a different approach altogether in solving plant production problems. His definition of cycle time includes basic work content and extra work content. Basic work content characterizes the necessary operations for a job and the extra work content, redundant operations for a job. The extra work content is broken into four categories.

1. Poor product design.
2. Poor manufacturing methods.
3. Poor management.
4. Poor workers.

POOR PRODUCT DESIGN: Design for versatility, easy maintenance, economy, lightweight and compactness. Also recommended are the usage of standardized parts/tooling and equipments. The lack of standardization splits production volume between multiple lots and sizes, of different models, increases paperwork and makes supply of spare parts difficult. The other two areas to be sought out are incorrect quality standards, and wastage of material and energy. Engineers have a tendency to overdesign due to their overcautious nature and add redundancy in systems design with large safety factors. As a personal example, I have designed air-conditioning systems with standby compressors/compressor motors. In the same manner, standby production/processing equipment is not required but it is first class preventive maintenance that is needed. Material wastage is due to defects in processing operations and use of substandard methods.

**POOR MANUFACTURING METHODS:** These could be improved by better tooling with appropriate selection and improved design, better layout to minimization of distances travelled and improvement over poor work methods. Also use material in standardized containers (lots).

**POOR MANAGEMENT:** Poor Management control with insufficient/inappropriate standardization, bad product design, poor production scheduling, incorrect preventive maintenance and poor quality.

Chase and Aquilano follow a different approach: They feel that when the production function has reached steady state, the focus of activity is on searching for refinements in the ongoing system. At this stage, the major problems in the design of the product and methods of production have been ironed out. Although considerable overlap occurs when one tries to group functional areas into some sort of improvement framework, it is useful to think of such efforts in four main categories:

- 1) Improvement related to product design and material specification. The design of a product commits the production system to specific processing methods; therefore the greatest opportunity for cost savings occurs during the initial design phase. Once the manufacturing process is under way, however cost reductions may be possible through redesign, changes in processing methods, and the selection of components and materials.
- 2) Improvement related to the production transformation process: for an existing system, additional data coupled with

experience will invariably show opportunities for improvement in the facility layout, work methods, quality control procedures and maintenance systems.

- 3) Improving production planning and control: The old adage 'plan the work and work the plan' is every bit as salient now as when it was coined. Indeed, detailed development of the production plan and careful execution of that plan are of critical importance because of the complexity of modern production distribution systems.
- 4) Improving labor performance: In the improvement of an existing system, the concentration should also be on the man in the system and developing his motivation for achieving a greater and higher quality production while at the same time assuring his contentment with the job. With the exception of employee suggestion plans, the incentive wage payment and zero defects programs accept the existing system as given and try to increase its efficiency. The employee suggestion plans leads to new designs and methods.

Hall offers a more detailed discussion on the implementation. This would occur in roughly four phases, as outlined:

1. Conceptualization: Learning, devising strategy, planning and developing confidence. This stage involves a development of generalized ideas about the nature of necessary changes and programs that are to be initiated.
2. Preparation: This involves putting the above plans in action, viz: revising the plant, reducing set up times, improving

process capability, and improving plant house keeping to a point where conversion to a pull system is physically possible.

3. Conversion: Changing from whatever method of material control now prevails to a pull system for the entire plant.
4. Consolidation and continued improvement: After the plant is basically operating by a pull system, much further improvement is possible, and the system can be the basis for evolving into full automation by whatever technological means seem feasible.

I feel that point 2 leads to point 3, as preparation sets up a firm ground for JIT implementation. Hall proposes implementation by the following procedure:

1. Top Management Education: Unless the top management knows about stockless production in a comprehensive manner, they would not be able to carry out the implementation. If they barely give assent to a program whose scope they have not grasped, they will be lost in corporate conflicts that will ensue. During implementation, a key member of top management acts as a champion of the implementation program.
2. Setting up the Implementation Team. The implementation team consists of those persons responsible for making the major changes at the plant floor level and within other detailed

operations. This team needs to have the most detailed preparation, for they are the ones who must lead the plant floor through the confusion of change. Even middle management and workers need to be educated as everyone on the staff is required to have a general concept because everyone will be involved in projects to change the existing plant operations.

3. Involve all people and develop an understanding of the JIT methodologies. If inventory is decreased without people being mentally and emotionally ready to overcome the problems that were the cause of the inventory reduction, stockless production will not come about.
4. Initiate a physical action program by working with pilot projects to serve as a demonstration activity and create/enhance awareness in the plant.
5. Eliminate confusion and make the problems clear by organizing the production area without making any radical changes in the current production planning and control system.
6. Improve process capability and QC procedures.
7. Reduce set up: A major activity that should be run concurrently with 5. Only if lead times are small can the JIT implementation becomes feasible.
8. Synchronized material handling design to provide



components where required and only when needed.

9. Revise a final assembly area to accept a level production schedule.

The above approaches lead to the same objective, but with different ideas. The common factors among all these methods are following:

1. Identify problem.
2. Improve existing methods, techniques, layouts and equipment to solve the problems.
3. Encourage everyone involved to participate in improvement program.
4. Begin with a pilot project, a particular department, centrally located, and is accessible to all other related activity centers.
5. Reduce inventory, set up.
6. Improve operations and quality.

Here, it needs to be mentioned that different American industries who pioneered in JIT implementation have achieved spectacular progress. Yet their method of basic information flow is not cards (kanban). Harley Davidson uses standard sized tote carts (similar to carts in grocery store), Hewlett Packard uses demarked material storage areas, while TOYOTA, follows its original card control system. These examples prove that card control is not the only one possible. This implies that, a worker must watch his output area - if it is empty, then, he needs to produce, otherwise not produce.

We attempt to develop a non specific approach that does not depend on any standardized text book pattern, as we realize the individuality of every plant. Our technique is,

1. Identify problems. If one cannot find such problems then he should start looking into functional areas if problems exist in them. He needs to observe activities in terms of layout planning, production control, quality control, inventory control, maintenance, product design etc.,.
2. Select a representative team involving personnel with a diversity of experience in a variety of production activities. This team has to "educate" top management and "create awareness" among the lower line managers.
3. Improve existing methods, techniques, equipment and layout to solve these problems. Improvements addressed to specific areas deserving attention.
4. Reduce set up times to reduce lead times. Also improve material transport.
5. Expand awareness among people about JIT. Let people make their own decisions- provide training on basic skills across functional lines. This encourages flexibility and versatility, and creates problem solving and decision making atmospheres at lower levels. Also reduce the number of job categories so that people are more acceptable to each other and a

"friendly atmosphere" is created.

6. Select a particular department and initiate material control that follows a pull methodology - manufacturing only on demand.
7. Improve product design, enhance preventive maintenance and follow QC by improving production process and not through inspection to pick out bad parts.
8. Gradually and systematically introduce this material control into other areas in a progressive manner.
9. Use this system to cut down inventory levels.
10. Interchange between 8 and 9 to progressively improve operations: as any activity can always be improved.
11. Achieve the objective of:
  - i) Flexibility in production, plant and processes.
  - ii) Top class preventive maintenance to increase reliability of machinery and equipment.
  - iii) Enhanced coordination between plant personnel and workers.
  - iv) Reduction in set up time, improvement in quality.

- v) Balanced production flow.
- vi) Integrated process lines.
- vii) Elimination of delays in production.
- viii) Reduction in number of management divisions and extended decision making activities to floor level.

## SUMMARY

The objective of providing a maximum customer service , yet with low investments, can be achieved only with efficient plant control. Production management plays a very crucial role in keeping plant operations efficient, but still problems remain. These problems are caused by the variability in demand, diversification of the manufacturing process, and a large number of components and manufacturing stages. There have been progressive improvements in production control, to deal with these problems. Even different production schemes have been tried, and those that support repetitive manufacturing have been more succesful, as the qualities of flexibility, integrity and coordination are inherent in repetitive manufacturing.

Instead of designing production control systems for a complex manufacturing environment, the simplification of the process operation itself will minimize problems of production control. Productivity improvement in production operations can be achieved by reducing inventory.

Excess inventory is due to large set ups, and it then acts as a safety valve to encourage additional production to cover up set up losses. Cut down set ups either independently or through a combination of design, trained procedure and improved tooling. Also large inventories lead to low turnover rates. High turnovers require flexible operations that can accept variable demand,

design changes, changes in product mix and changes in product rates.

The extent to which a production control system is implemented depends upon the nature and limitation of the process operations that are to be controlled. The intractability in MRP shows up with the change in higher level needs when the lower level execution has already begun. Buffering demand changes by increasing the safety stock is not an advisable method, as it increases lead time, distorts priorities and consumes resources before they are really needed. MRP does not provide the ability to group product items at intermediate levels in the production structure. MRP also does not insure that the capacities are available, it preassumes that capacities are available. Additional problems in MRP are triggered by increase in throughput time of an item or its lot sizes. When lot sizes reduce to "single digits", MRP would fail (Heard, 1984).

JIT works inspite of lack of forecasting abilities of lower level production process. It however fails with changing master production schedules and inappropriate dispersion of resources.

The main idea of JIT is to produce only if the requirement for the part exists. It is characterized by synchronized material movement and control of pipeline inventory. With the prerequisites of substantial revision of equipment and coordinated layout, JIT satisfies a three fold objective of well coordinated production on a flexible line and with a control over the range of jobs assigned to each worker. Four different types

of layouts- cellular, bird cage, isolated islands and dedicated lines were considered. However, the disparity of opinion regarding dedicated lines could not be solved. Cellular layout scores over the other three in terms of efficiency. Now, if the inventory is to be kept on floor and not in stock rooms, then work centers have to be defined and organized. The method of operation is through card control- move card circulates between work centers and production card circulates at a single work center only.

Work rules (page 32) are followed to achieve an efficient control- requires and inculcates coordination and flexibility among operators. The number of cards issued to each work center is proportional to the work in process inventory allowed for each part number. There are other variations of material transport signals. We observed that this method of material transport (cards, checkers, or other devices) aid in smooth material flow between work centers, makes recording of material transfer unnecessary and different types of markers are used, each for a specific reason. To keep track about status of ongoing activities, "Andon" or electric scoreboards display information. They are also useful for enhancing responsibilities so that the worker can work with multiple work stations.

The master production schedule is based on a quarterly demand forecast and is prepared every month. The Kanban smoothes or fine tunes MPS and the sequence schedule specifies the assembly order of different product models in the final assembly line.

As Kanban takes the instructions backward, the preceding

processes do not need their own particular schedule in advance.

The objective of balanced production is to achieve high productivity through efficient operations, coordinated line balancing and maintenance of a minimum quantity of WIP inventories. The standard operations are determined by a preliminary determination of its components. In establishing the worker's assignments for the order of process, emphasis is laid on one shot set-up.

Initiating an implementation program in a company is difficult. This actually depends on the status of production when the implementation is initiated. Consideration of the proposed and discussed criteria need to be carried out before actual implementation.

Before actual implementation plans are executed, the problems in existing production system need to be determined and solved. Further, the variety in the improvement methods, as suggested by different management experts indicate that there is no "formula" for implementation programs. A few important features among these proposed methods are common, and based on these features we have proposed our implementation scheme.



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ACHIEVEMENT OF EFFICIENT OPERATIONS CONTROL  
THROUGH JUST IN TIME PRODUCTION MANAGEMENT

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AN ABSTRACT FOR  
A MASTER'S REPORT

submitted in partial fulfillment of the  
requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1985

## ABSTRACT

Recent manufacturing trends such as group technology (GT), & flexible manufacturing systems (FMS) have provided the capability of manufacturing a wide variety of parts in small lots. But the large number of components involved through multiple stages of manufacture coupled with high variability in production at each stage has caused actual figures to deviate from planned figures. Even with the recent state of art systems and software, problems such as excessive WIP inventories, long lead times and quality problems are still in persistence.

By replacing complexity with simplicity in manufacturing management, JIT has achieved reduced inventories, efficient plant operations and enhanced quality. This project aims at the study of JIT and MRP systems. We attempt to integrate JIT approach into MRP plan so that existing production problems can be worked out efficiently. The study of efficient inventory management, leads the way to efficient implementation, and reasons will be sought through discussion of implementation criteria.

Past research has concentrated on inventory management. Presently the major problems are in inventory management, quality control and achieving operations flexibility. As new problems arise, future research is required to solve them and achieve better operations control.

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